Cheese Yield Evaluations: Improving the Quality of Cheese Composition Data

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NYS Cheese Manufacturers’ Association
Syracuse, NY
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Outline

- Introduction
- Metrics of Cheese Yield Performance
- Improving Cheese Yield Performance
- A Cheese Yield Performance Evaluation System
- Sensitivity of Performance Evaluation to Input Data Quality
- Methods of Cheese Composition Analysis
- Conclusions
Introduction – Important Information on Factors Influencing Cheese Yield

1890’s – VanSlyke Cheese Yields in NYS
1978 Cheese Yield Studies in New York State
1984 National Milk Composition Study
IDF – Cheese Yield and Factors Affecting Its Control
Conference 1993 – Cork Ireland
Outline

- Introduction
- Metrics of Cheese Yield Performance
Barbano Theoretical Generalized Cheese Yield Formula

\[(A+B+C)\]

\[Yield = \frac{1 - (\text{target cheese moisture + target cheese salt})}{100}\]
Barbano Theoretical Generalized Cheese Yield Formula

\[ \text{Yield} = \frac{(A+B+C)}{1 - \left(\frac{\text{target cheese moisture} + \text{target cheese salt}}{100}\right)} \]

\[ A = (\text{percentage of fat recovery in cheese}) \times (\text{percent fat in milk}) \]
Metrics of Cheese Yield Performance

Barbano Theoretical Generalized Cheese Yield Formula

\[
\text{Yield} = \frac{(A+B+C)}{1 - \frac{(\text{target cheese moisture} + \text{target cheese salt})}{100}}
\]

A = \text{(percentage of fat recovery in cheese) x (percent fat in milk)}

B = \text{(percent casein in milk – 0.1) x (calcium phosphate retention factor)}
Barbano Theoretical Generalized Cheese Yield Formula

\[
\text{Yield} = \frac{(A+B+C)}{1 - \left( \frac{\text{target cheese moisture} + \text{target cheese salt}}{100} \right)}
\]

\( A = (\text{percentage of fat recovery in cheese}) \times (\text{percent fat in milk}) \)

\( B = (\text{percent casein in milk} - 0.1) \times (\text{calcium phosphate retention factor}) \)

\( C = \left[ \frac{(A+B)}{1 - \left( \text{actual cheese moisture percent}/100 \right)} \right] - (A+B) \times (\text{separated whey solids percent}/100) \times (\text{solute exclusion factor}) \)
Barbano Theoretical Generalized Cheese Yield Formula

\[
\text{Yield} = \frac{(A + B + C)}{1 - ((\text{target cheese moisture} + \text{target cheese salt})/100)}
\]
Barbano Theoretical Generalized Cheese Yield Formula

\[
Yield = \frac{(A+B+C)}{1 - \left(\frac{(target\ cheese\ moisture + target\ cheese\ salt)}{100}\right)}
\]

A = 3.674 x .93 = 3.417
B = (2.501 – 0.1) x 1.092 = 2.622
C = \[\left(\frac{(A+B)}{1-37.5/100}\right) - (A + B)\] x 6.45/100 x 0.70
Metrics of Cheese Yield Performance

Barbano Theoretical General Cheese Yield Formula

\[
\text{Yield} = \frac{(A + B + C)}{1 - \frac{\text{(target cheese moisture + target cheese salt)}}{100}}
\]

\[A = 3.674 \times 0.93 = 3.417\]
\[B = (2.501 - 0.1) \times 1.092 = 2.622\]
\[C = \left[\frac{(3.417 + 2.622)}{(1 - 37.5/100)} - (3.417 + 2.622)\right] \times \frac{6.45}{100} \times 0.70 = 0.163\]

\[3.417 + 2.622 + 0.163\]

\[\text{Yield} = \frac{3.417 + 2.622 + 0.163}{1 - \frac{37.5 + 1.75}{100}} = 10.21\]
Outline

- Introduction
- Metrics of Cheese Yield Performance
- Improving Cheese Yield Performance
Factors to Focus On:

1) Milk supply – composition and quality
   - Fat and Protein
   - Bacteria count
   - Somatic cell count
Improving Cheese Yield Performance

Factors to Focus On:

2) Accuracy of parameters measured in the cheese factory
   • Cheese weight (type and specification on load cells)
   • Milk weight (meter type and specifications)
   • Milk and whey composition
     • Mid-infrared analyzer
   • Cheese Composition
     • Classical chemistry methods
     • Near-infrared
     • Mid-infrared??
Factors to Focus On:

3) Control of cheese composition (accuracy and variability)

• Process control

• Vat-to-vat, day-to-day variation
Factors to Focus On:

4) Reduction in loss of fat and protein during the process

• Measuring whey composition
Outline

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- A Cheese Yield Performance Evaluation System
# Daily Output Data

<table>
<thead>
<tr>
<th>Composition Control</th>
<th>Past Cheddar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target fat on dry basis (%)</td>
<td>53.29</td>
</tr>
<tr>
<td>Actual fat on a dry basis (%)</td>
<td>53.29</td>
</tr>
<tr>
<td>Fat on a dry basis standard deviation (vat-to-vat variation) (%)</td>
<td>0.00</td>
</tr>
<tr>
<td>Fat gain or loss due to deviation from target (lbs)</td>
<td>0.00</td>
</tr>
<tr>
<td>Target moisture (%)</td>
<td>37.50</td>
</tr>
<tr>
<td>Actual moisture (%)</td>
<td>37.50</td>
</tr>
<tr>
<td>Moisture standard deviation (vat-to-vat variation) (%)</td>
<td>0.00</td>
</tr>
<tr>
<td>Moisture gain or loss due deviation from target (lbs)</td>
<td>0.00</td>
</tr>
</tbody>
</table>
## Daily Output Data

### Composition Control

<table>
<thead>
<tr>
<th></th>
<th>Past Cheddar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target salt (%)</strong></td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Actual salt (%)</strong></td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Actual salt-in-moisture (%)</strong></td>
<td>4.67</td>
</tr>
<tr>
<td><strong>Salt standard deviation (vat-to-vat variation) (%)</strong></td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Salt gain or loss due deviation from target (lbs)</strong></td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Target fat on a wet basis (%)</strong></td>
<td>33.31</td>
</tr>
<tr>
<td><strong>Actual fat on a wet basis (%)</strong></td>
<td>33.31</td>
</tr>
<tr>
<td><strong>Fat on a wet basis standard deviation (vat-to-vat variation) (%)</strong></td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Target 4 day cheese pH (-)</strong></td>
<td>5.05</td>
</tr>
<tr>
<td><strong>Actual 4 day cheese pH (-)</strong></td>
<td>5.05</td>
</tr>
<tr>
<td><strong>pH standard deviation (vat-to-vat variation) (-)</strong></td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total cheese yield gain or loss per day (lbs)</strong></td>
<td>0.00</td>
</tr>
</tbody>
</table>
Outline

• Introduction
• Metrics of Cheese Yield Performance
• Improving Cheese Yield Performance
• A Cheese Yield Performance Evaluation System
• Sensitivity of Performance Evaluation to Input Data Quality
Accuracy of Cheese Analysis – What is the impact?

Moisture – there is a moisture target for each cheese type, if the moisture for the day is lower than the target you miss an opportunity for higher yield and if the moisture is higher than your target you can gain yield but may risk have a negative impact on cheese quality. This is straightforward assuming the moisture test results are correct.

In a plant converts about 2 million pounds of milk to cheese in a day, the impact running 0.5% low on moisture is about 1050 pounds of cheese for the day, assuming the moisture test is correct. What if the test is not correct?
Sensitivity of Performance Evaluation to Input Data Quality – Testing Accuracy

Accuracy of Cheese Analysis – What is the impact?
What if the moisture test is not correct for Cheddar?

<table>
<thead>
<tr>
<th>Cheese</th>
<th>Reference Test Actual Moisture</th>
<th>QC - Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>37, 37.1, 37.2, 37.3, 37.4, 37.5</td>
<td>37.5</td>
</tr>
<tr>
<td>Yield Loss (lbs/day)</td>
<td>1066, 853, 640, 426, 213, 0</td>
<td>0</td>
</tr>
<tr>
<td>Yield Loss (lbs/year)</td>
<td>389127, 311301, 233476, 155651, 77825, 0</td>
<td>0</td>
</tr>
</tbody>
</table>
**Sensitivity of Performance Evaluation to Input Data Quality – Testing Accuracy**

**Accuracy of Cheese Analysis – What is the impact?**

**What if the salt test is not correct for Cheddar?**

<table>
<thead>
<tr>
<th>Cheese</th>
<th>Reference Test</th>
<th>Actual Salt</th>
<th>Yield Loss (lbs/day)</th>
<th>Yield Loss (lbs/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
<td>1.50</td>
<td>1.55</td>
<td>1.60</td>
<td>1.65</td>
</tr>
<tr>
<td>QC Salt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield Loss</td>
<td>533</td>
<td>426</td>
<td>320</td>
<td>213</td>
</tr>
<tr>
<td>Yield Loss (lbs/year)</td>
<td>194545</td>
<td>155490</td>
<td>116800</td>
<td>77745</td>
</tr>
</tbody>
</table>
Sensitivity of Performance Evaluation to Input Data Quality – Testing Accuracy

Accuracy of Cheese Analysis – What is the impact?

What if the fat test is not correct for Cheddar?

<table>
<thead>
<tr>
<th>Cheese</th>
<th>Reference Test Actual Fat</th>
<th>QC - Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>32.8 32.9 33 33.1 33.2 33.3</td>
<td></td>
</tr>
<tr>
<td>Yield Loss (lbs/day)</td>
<td>1066 853 640 426 213 0</td>
<td></td>
</tr>
<tr>
<td>Yield Loss (lbs/year)</td>
<td>389127 311301 233476 155651 77825 0</td>
<td></td>
</tr>
<tr>
<td>Fat Recovery(%)</td>
<td>91.60 91.88 92.16 92.44 92.72 93.00</td>
<td></td>
</tr>
</tbody>
</table>
What about **Low Moisture Part Skim Mozzarella**?  
What if the tests are not correct?

<table>
<thead>
<tr>
<th>Cheese</th>
<th>Reference Test</th>
<th>Actual</th>
<th>QC - Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>47.5</td>
<td>47.6</td>
<td>47.7</td>
</tr>
<tr>
<td></td>
<td>47.8</td>
<td>47.9</td>
<td>48.0</td>
</tr>
<tr>
<td>Yield Loss</td>
<td>243820</td>
<td>194910</td>
<td>146365</td>
</tr>
<tr>
<td>(lbs/year)</td>
<td></td>
<td></td>
<td>97455</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>48910</td>
</tr>
<tr>
<td>Fat</td>
<td>19.7</td>
<td>19.8</td>
<td>19.9</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>20.1</td>
<td>20.2</td>
</tr>
<tr>
<td>Yield Loss</td>
<td>243820</td>
<td>194910</td>
<td>146365</td>
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<tr>
<td>(lbs/year)</td>
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<td></td>
<td>48910</td>
</tr>
<tr>
<td>Salt</td>
<td>1.50</td>
<td>1.55</td>
<td>1.60</td>
</tr>
<tr>
<td></td>
<td>1.65</td>
<td>1.70</td>
<td>1.75</td>
</tr>
<tr>
<td>Yield Loss</td>
<td>121910</td>
<td>97455</td>
<td>73000</td>
</tr>
<tr>
<td>(lbs/year)</td>
<td></td>
<td></td>
<td>48910</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>24455</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
Sensitivity Analysis

1. The sensitivity of management decisions to the accuracy of all measured parameters can be determined systematically. The impact increases as plant capacity increases.

2. The most important measured parameters are: a) milk and cheese analysis and b) milk and cheese weight determination.

3. The economic impact can be calculated and can be used as guide on how much to invest in enabling the management system to have sound data on which to make decisions.
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Cheese Composition: testing options

Classical chemistry methods (slow but accurate when done correctly)

• Fat - Babcock, Gerber, ether extraction
• Protein – Kjeldahl
• Moisture – forced air oven or vacuum oven
• Salt – Volhard silver nitrate titration or chloridometer type salt meter
Cheese Composition: testing options

NIR Cheese Analysis (rapid and simple sample preparation)

- Parameters measured – fat, protein, moisture, and salt
- Local NIR calibration (very difficult and extensive calibration required for each cheese type)
- Global NIR calibrations (less calibration cost)
- Standard Error of Prediction for NIR of cheese components are in the range of 0.2 to 0.4% (Holroyd, 2011. NIR News. 22 (6) p 9-11)
Cheese Composition: testing options

MIR Cheese Analysis (new research)

Goal to improve accuracy (i.e., lower Standard Error of Prediction and develop a more simple global calibration for Cheddar cheese)

• Parameters measured – fat, protein, moisture, and salt.
• Instrument: Delta FTA
• Sample Preparation: Blend the cheese with a buffer and analyze the cheese on the same MIR analyzer used for milk and whey analysis.
• Calibration with a set of liquid cheese standards
MIR Cheese Analysis (new research)

Method:

1) Warm cheese solver solution to 65°C
2) Weigh 81 g of 65°C solver and add to stainless steel Eberbach blender jar
Cheese Composition: Sample Preparation

MIR Cheese Analysis (new research)

Method:

1) Warm cheese solver solution to 65°C
2) Weigh 81 g of 65°C solver and add to stainless steel Eberbach blender jar
3) Weigh 9 g of cheese and added to the blender jar containing the solver
4) Add 3 drops of antifoam
5) Blend at low speed for 15 seconds and the increase to high speed for 45 seconds.
6) Pour the liquid into a 4 oz plastic snap lid and place into 40°C water bath.
7) After 20 to 30 minutes test on the Delta FTA like a milk sample.
Cheese Composition: MIR testing

MIR Cheese Analysis (new research) – Delta FTA

1) For fat and protein used the optimized sample and reference wavelengths used to measure fat and protein content of milk with the same intercorrection factors used for milk.

2) For salt we used a combination of the infrared spectra and an in-line conductivity sensor in the MIR milk analyzer.

3) For total solids the we added the fat, protein, and salt calibrated results and did a final slope and intercept using oven drying total solids reference value on cheese samples.
MIR Cheese Analysis (new research) – Delta FTA

\[ y = 1x - 5E-05 \]
\[ R^2 = 0.9057 \]

Fat prediction

Reference Fat

- 0.001 MD
- 0.124 SDD
- 0.367 CV
- 0.128 Standard Error of Prediction
Cheese Composition: MIR Results

MIR Cheese Analysis (new research) – Delta FTA

Protein prediction

\[ y = 1x - 1E-06 \]

\[ R^2 = 0.8792 \]

-0.001
0.092 SDD
0.379 CV
0.094 Standard Error of Prediction
Cheese Composition: MIR Results

MIR Cheese Analysis (new research) – Delta FTA

\[ y = 1x + 0.0017 \]
\[ R^2 = 0.7592 \]

Reference Moisture

Mid IR moisture

MIR predicted Moisture

-0.001

0.195 SDD

0.531 CV

0.201 Standard Error of Prediction
Cheese Composition: MIR Results

MIR Cheese Analysis (new research) – Delta FTA

Salt prediction

\[ y = 1x + 7E-06 \]
\[ R^2 = 0.8509 \]

Reference Salt

Salt - IR Prediction

0.000
0.033 SDD
1.953 CV
0.034 Standard Error of Prediction
1. Standard Error of Prediction on moisture was equal to best performance by NIR analysis of cheese.

2. Standard Error of Prediction for fat, protein and salt were better than those reported for NIR analysis of cheese.

3. Further work is need to determine if the calibration for Cheddar cheese is valid across manufacturing plants.
Future Work

• The approach for Cheddar cheese analysis will be tested on Mozzarella cheese, cottage cheese, cream cheese, and sour cream.

• Once we get good at measuring composition of Cheddar cheeses, we would like to determine if we could predict parameters that relate to flavor quality development during cheese aging.