Pasteurized Milk Feeding Systems: Capturing the Benefits and Avoiding the Pitfalls

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Outline:

• Pasteurizing milk:
  – Types of milk pasteurization systems
  – Potential benefits
  – Making the system work for you:
    • Avoiding the pitfalls
    • Monitoring

Pasteurization

• Non-saleable milk = transition + treated milk

• Heat milk to a target temperature and for a target period of time for a given microbe.

• Goal: Reduce or eliminate pathogen exposure to calves.

• Pasteurization ≠ Sterilization
NAHMS, 2007 Dairy Study

<table>
<thead>
<tr>
<th>Milk fed</th>
<th>Small dairies &lt; 100</th>
<th>Medium 100-499</th>
<th>Large 500+</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasteurized milk</td>
<td>2.3%</td>
<td>4.6%</td>
<td>31%</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

Pasteurizer Designs:
Batch Pasteurizers
- 145 °F (63 °C) x 30 minutes
- 10 – 150 gallon batches
- 1.5 to 3+ hrs (depends on batch size)
- Agitator
- Automated heat & cool cycle
- Manual wash
- Cost: $5000 - $10,000

DairyTech 30 batch pasteurizer

Pasteurizer Designs:
Continuous Flow
- Flash or High Temperature/Short Time (HTST)
- 161 °F (72 °C) x 15 seconds
- 1 to 40 gallons per minute
- Automated heat & cool cycle
- +/- Automated CIP wash system
- Cost: $20,000 - $40,000+

CalfStar, Inc.
Pasteurizer Designs:
Ultraviolet Radiation

- UV light passed through column of milk (200 to 280 nm = germicidal range)
- 50, 100 or 150 gallon batches
- 1.5 – 2 hours/batch
- Cost: $18,000 - $20,000
- Concern that opaque/turbid liquids attenuate and scatter UV radiation resulting in less microbial inactivation (Viljoen and Lourens-Hattingh, 2002)
- Emerging research suggests poorer efficacy in killing bacteria

From: Centre for Dairy Research, Madison, WI

<table>
<thead>
<tr>
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<th>Batch (145°F, 30 min)</th>
<th>HTST (161°F, 15 sec)</th>
<th>UV</th>
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<tr>
<td>Salmonella spp.</td>
<td>Yes</td>
<td>Yes</td>
<td>NAv</td>
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<tr>
<td>Listeria monocytogenes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>E. coli</td>
<td>Yes</td>
<td>Yes</td>
<td>Low-Mod</td>
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<td>Staph. aureus</td>
<td>Yes</td>
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<tr>
<td>M. bovis, M. californicum</td>
<td>Yes</td>
<td>Yes</td>
<td>NAv</td>
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<tr>
<td>Crypto. parvum</td>
<td>NAv</td>
<td>Yes</td>
<td>NAv</td>
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<tr>
<td>Bovine Leukemia Virus</td>
<td>Yes</td>
<td>Yes</td>
<td>NAv</td>
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<tr>
<td>M. paratuberculosis</td>
<td>Yes</td>
<td>Mostly*</td>
<td>Poor</td>
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* Some studies saw regrowth if inoculate MAP at very high concentrations
Does Pasteurization Kill Pathogens in Milk and Colostrum?

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Summary of UV Research to date…

- UV treatment of milk:
  - Intermediate ability to inactivate ‘regular’ bugs (e.g. E. coli, S. aureus, Environmental Strep. spp.)
  - Poorer efficacy vs heat-based pasteurization methods: UV: 3.3 log reduction; HTST: 5.2 log reduction (Bicalho et al., 2013)
  - Poor ability to inactive MAP (Johne’s)

- UV treatment of colostrum:
  - 43-50% denaturation of IgG

(Reinemann et al., 2006; Altic et al., App Env Micro 2007.73:3728; Donaghy et al., 2009. Bicalho et al., 2013; Pereira et al., 2014; Gelsinger et al., 2014)
**Potential benefits from feeding pasteurized milk**

1. Improved health by reducing pathogen transmission (vs raw milk)
2. Improved rate of gain (vs conventional milk replacer (CMR))
3. Improved calf health (vs. CMR)
4. Improved economic efficiency (vs. CMR)
5. Utilization of non-saleable product (disposal issue)

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**1. Reduced Pathogen Transmission (vs raw milk)**

CA Study: Pasteurized vs Raw Milk & Colostrum

- 300 CA calves fed either:
  a) Pasteurized colostrum and non-saleable milk (n=150)
  b) Raw colostrum and non-saleable milk (n=150)
- Benefits include higher weight gain, lower mortality, fewer days affected with diarrhea and pneumonia
- Calves fed pasteurized milk were worth an extra **$8.13** in gross margin/calf (vs calves fed raw milk)
- Est. economically feasible at 315 calves per day


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**2. Improved Rate of Gain vs Conventional Milk Replacer**

Predicted Daily Gain for 100 lb Calf at 68°F Ambient Temperature

<table>
<thead>
<tr>
<th></th>
<th>Milk Replacer (20:20)</th>
<th>Whole Milk (25:29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeding Rate</td>
<td>1 lb DM/d</td>
<td>4 quarts/d</td>
</tr>
<tr>
<td>Predicted ADG</td>
<td>0.38 lb/d</td>
<td>0.78 lb/d</td>
</tr>
</tbody>
</table>

- Fed at traditional rates, calves fed whole milk should grow better due to increased energy and protein intake (vs CMR).
- If match nutrients in milk replacer vs whole milk: Results depend on quality of milk replacer (Lee et al., 2009. J. Anim. Sci. 87:1129-1137)
2. Improved Rate of Gain

MN Field Study: Pasteurized Milk vs 20:20 Milk Replacer

- 439 calves enrolled from 2 dairies:
  - Dec., 2001 to Aug., 2002
- Treatment Groups:
  - Batch pasteurized non-saleable milk from Johne's infected dairy (10-12% seroprevalence) (DairyTech, Inc. Windsor, CO)
  - 20:20 milk replacer
- Facilities: two greenhouse barns

Parameter & Milk Replacer & Pasteurized Milk & P value < 0.05 \\
--- & --- & --- & --- \\
Calves enrolled (n) & 217 & 222 &  \\
Serum Total Protein (mg/dl) & 5.7 & 5.8 &  \\
Arrival Weight (lb) & 88.3 & 87.5 &  \\
Age at Weaning (d) & 47 & 46 &  \\
Weaning Weight (lb) & 133.9 & 146.3 * &  \\
Preweaning Gain (lb) & 45.0 & 58.9 * &  \\
Avg. Daily Gain (lb/d) & 0.76 & 1.04 * &  \\

3. Improved Calf Health – Minnesota Field Study

Preweaning Treatment Rate (%)

Significant reduction in scours and pneumonia for all months
3. Improved Calf Health – Minnesota Field Study

**Preweaning Death Loss (%)**

![Graph showing preweaning death loss by month of birth and milk type.](image)

Significant reduction in death losses in winter months

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4. Improved Economic Efficiency

**MN Field Study: Pasteurized Milk vs 20:20 Milk Replacer**

- **Results**
  - Relative cost advantage of pasteurized non-saleable milk system:
    - $0.69 per calf per day
    - $34 per calf weaned
  - Breakeven analysis:
    - 23 calves fed/day
- Followed to avg 57 months of age to measure impact on Johne’s disease, longevity and performance

- [www.cvm.umn.edu/dairy/software/listing](http://www.cvm.umn.edu/dairy/software/listing)

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**Adult Cow Performance**

- From 1st calving to avg. 57 months
(Linear or Logistic regression, herd = random effect)

<table>
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<tr>
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<th>Milk Replacer</th>
<th>Pasteurized Milk</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cows w first calving event</td>
<td>54</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Milk yield (lact &gt; 150 DIM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lact 1 (kg)</td>
<td>11,200</td>
<td>11,370 (+170)</td>
<td>0.81</td>
</tr>
<tr>
<td>Lact 2 (kg)</td>
<td>11,246</td>
<td>13,257 (+2,011)</td>
<td>0.004</td>
</tr>
<tr>
<td>Sum Lact 1 &amp; 2 (kg)</td>
<td>22,028</td>
<td>23,964 (+1,935)</td>
<td>0.084</td>
</tr>
<tr>
<td>% culled or died</td>
<td>53.7%</td>
<td>41.5%</td>
<td>0.036</td>
</tr>
<tr>
<td>% MAP positive</td>
<td>27.8%</td>
<td>21.5%</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Differences significant if P < 0.05
Risk for Infection with *M. paratuberculosis*
- From 1st calving to avg. 57 months
(Survival analysis using PHREG in SAS, herd = random effect)

![Graph showing risk for infection with PHREG in SAS](Image)

Hazard Ratio Milk Replacer = 1.38 (P = 0.36)

Lifetime Risk for Culling or Death
- From birth to avg. 57 months
(Survival analysis using PHREG in SAS, herd = random effect)

![Graph showing lifetime risk for culling or death with PHREG in SAS](Image 2)

Hazard Ratio Milk Replacer = 1.81 (P = 0.0037)

Summary of potential benefits from feeding pasteurized milk

1. As compared to raw milk:
   a) Improved health by reducing pathogen transmission

2. As compared to a conventional milk replacer:
   a) Improved rate of gain
   b) Improved calf health
   c) Improved longevity and future performance
   d) Improved economic efficiency (vs. CMR)

3. Utilization of non-saleable product (disposal issue)
Making the system work for you:

Avoiding the pitfalls

1. Need for more intensive management
2. Avoid pasteurization failure by managing entire system correctly
3. Avoid inconsistent nutrient composition
4. Develop strategy for inadequate milk supply
5. Monitoring
6. Concerns about antimicrobial residues

1. Need for more intensive management

Planning and Managing Pasteurized Milk Feeding Systems

• Planning and Installation:
  – Housing / location of equipment
  – Water, electrical & drainage supply
  – Installation (support?)
  – Develop system to collect, store and transport raw and pasteurized milk

• Operation:
  – Training
  – Protocols for handling raw and pasteurized milk
  – Pasteurization protocols
  – Cleaning protocols
  – Monitoring protocols
  – Service support

2. Risk of Pasteurization Failure

Risk of Pasteurization Failure if SYSTEM Not Managed Correctly
2. Risk of Pasteurization Failure
Risk of Pasteurization Failure if SYSTEM Not Managed Correctly

Avoid contamination during harvest & transfer of raw milk

How is raw milk handled on the way to the pasteurizer?

Problem: Excessive Bacterial Growth in Improperly Stored Raw Milk

(Reynolds, 2002)
One Cause of Pasteurization Failure:
Start with too many bugs!

- Improper storage of raw milk:
  - Bacteria multiply quickly at warm temps
  - Unchilled milk: > 1 billion CFU/ml in summer

- Pasteurization does NOT equal sterilization
  - If pasteurizer removes 99% of bacteria:
    
    | Pre        | Post       |
    |------------|------------|
    | 50,000     | 500        |
    | 1 billion  | 10 million |
    (cfu/ml)   (cfu/ml)

Do NOT pasteurize soured (spoiled) milk

- Fermentation of non-chilled milk
- Acid production (pH < 4.7)
- Curd formation
- Add heat

Risk of Pasteurization Failure
Risk of Pasteurization Failure if SYSTEM Not Managed Correctly

Avoid bacterial proliferation in raw milk:
- Pasteurize within 2 hrs
- Rapidly chill raw milk
2. Risk of Pasteurization Failure

Risk of Pasteurization Failure if SYSTEM Not Managed Correctly

Does the pasteurizer work?

Monitor:
- Times & temps
- Rapidly cool
- Cleaning
- Bacteria counts

How is milk handled on the way to the calf?
- Avoid recontamination
Recontaminating Pasteurized Milk: A Weak Link
(J. Heinrichs and C. Jones. Hoard's Dairyman. 07/2011 pg. 442)

- 6 Pennsylvania farms
- 129 matched milk samples: pre-, post-pasteurized, calf bucket

<table>
<thead>
<tr>
<th>SPC (cfu/ml)</th>
<th>mean</th>
<th>range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-pasteurization</td>
<td>64,712</td>
<td>240 to 658,000</td>
</tr>
<tr>
<td>Post-pasteurization</td>
<td>5,877</td>
<td>0 to 250,000</td>
</tr>
<tr>
<td>Calf bucket</td>
<td>30,443</td>
<td>0 to 250,000</td>
</tr>
</tbody>
</table>

Avoid Post-Pasteurization Contamination

- Keep pasteurized milk in clean covered containers
- Feed shortly after pasteurization or else rechill milk until feeding time
- Sanitation of transfer hoses, storage tanks, bottles, buckets and nipples
- Monitor bacteria counts

2. Risk of Pasteurization Failure

Risk of Pasteurization Failure if SYSTEM Not Managed Correctly
2. Risk of Pasteurization Failure

Risk of Pasteurization Failure if SYSTEM Not Managed Correctly

Avoid contamination during harvest & transfer of raw milk

- Avoid recontamination
- Monitor:
  - Times & temps
  - Rapidly cool
  - Cleaning
  - Bacteria counts

Avoid bacterial proliferation in raw milk:
- Pasteurize within 2 hrs or
- Chill

3. Avoiding Inconsistent Nutrient Composition

Avoiding inconsistent nutrient composition of non-saleable milk?

- James et al., 2006
  - Study of 3 NC farms and 10 CA farms
  - Most samples had > 29% fat and 26% protein (DM basis)
  - Some samples had < 1.5% fat (norm = 3.8%) (as fed basis)

- To minimize variation in nutrient content:
  - Avoid flushing lines with too much water at end of milking
  - Agitate milk well prior to pasteurization and again, prior to feeding calves

Brix Refractometer to Monitor Total Solids in Milk
(Moore et al., 2009. J. Dairy Sci. 92:3503)

- Instrument:
  - Reichert Inc. (Depew, NY), $270
  - Capable of measuring TS in milk ranging between 5 – 15%
  - Instrument reads 2% points low (vs spectrophotometry)
    - Adjust Brix reading 2% points higher to estimate TS

- Evaluation of whole milk samples from 12 CA dairies:
  - Adjusted Brix TS readings: 5.1 to 13.4% (< 12 TS % in 6 of 12)

- If low TS results:
  - Fix the system at the source
  - Add milk replacer powder to increase TS

http://www.das.psu.edu/research-extension/dairy/nutrition
for pasteurizer evaluator spreadsheet
4. Inconsistent milk supply

Need strategy for inadequate milk supply

Options:
1. Add salable bulk tank milk
2. Add milk from high SCC cow
3. Extend with 28:20 milk replacer
4. Feed younger calves milk, older calves milk replacer.

5. Need to Monitor

Options for Monitoring the Pasteurized Milk Feeding System

- Pasteurizer function:
  - Times and temperatures – daily
  - Periodic Alkaline Phosphatase test
    - < 500 mL/mil
- Quality of Raw and Pasteurized Milk:
  - Culture of milk samples (weekly or monthly) (Cfar, 2003):
    - Raw milk: < 1,000,000 CFU/ml TPC
    - Pasteurized milk: < 20,000 CFU/ml TPC
  - Total solids content of milk
    - Whole milk 12.5% solids
    - 10-12% using Brix refractometer
  - pH (normal milk is 6.7. Expect trouble if < 5.0)

Field Studies of Pasteurization Systems

- Pasteurizer function:
  - Jorgenson and Hoffman, 2003; James, 2006:
    - WI study of 31 on-farm systems: 88% passed Alk Phos test
    - 3 NC farms: 100%, 85%, 82% of samples passed Alk Phos
- Milk quality:
  - Moore et al., 2009. JDSci 92:3503:
    - 12 CA dairies:
      - pH: avg = 6 (4.7 to 6.6) (expect 6.5 - 6.7)
      - Adjusted TS avg = 11% (5.1 to 13.4%) (expect ≥ 12.5%)
  - Elizondo-Salazar et al., 2010. JDSci 93:5509:
    - 6 PA herds:
      - Pasteurizer did excellent job but many recontaminated samples
- Message: NEED TO MONITOR!!!
Other Questions:

• How high can we go?
  – Hotter is NOT always better!
  > 175 °F (80 °C) can result in:
    • calcium and phosphorus precipitates
      => deposits interfere with heat exchange and cleaning
    • Protein denaturation and decreased fat availability
      => poor calf performance

• Take home messages:
  – Stay at or close to PMO temperature guidelines
  – Importance of agitator in batch pasteurizers => even mixing and heating
  – Do not repasteurize milk

Other Questions:

• Do I need to supplement waste milk with vitamins or minerals?
• Effect of normal pasteurization temperatures on vitamins:
  – Not sensitive: Vits. A, D, most B Vits: Riboflavin, B6, B12, Folic acid, Biotin
  – Heat sensitive: Vits. C, E, and Thiamin
    • However, low levels in milk => Importance as dietary source?
    – Research needed on supplementing vitamins to waste milk

• Minerals not affected by pasteurization but may be value to additional supplementation anyway...
  – Two NY herds feeding pasteurized milk (Teixeira et al., 2014. JDSci)
  – Injectable trace mineral supplement (Zn, Mn, Se, Cu) at 3d and 30d
  – Treated calves had reduced scours (41.7%) vs controls (49.7%)
  – No effect of supplementation on mortality or growth
  – Further research needed in more herds in different regions
  – What if using a ‘balancer’ with pasteurized waste milk?

Other Questions:

Concerns about antibiotic residues?

• Pasteurization does not inactivate antibiotics in milk.

• Concerns:
  – Violative residues in meat
  – Concern could lead to development of antimicrobial resistance in enteric pathogens => public health concern
  – Public scrutiny and research will continue
Pasteurized Milk Feeding Systems: Summary

- Potential Advantages:
  - Reduce pathogen transmission
  - Improved rate of gain
  - Improved calf health and future performance
  - Improved economic efficiency
  - Utilization of non-saleable product (disposal issue)

- Avoiding the pitfalls
  - Need for more intensive management
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Thank you!