Effect of Enhancement of Pork and Beef on Postmortem Events

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Overview

• Animal Metabolism
  – Ante-Mortem
  – Post-Mortem

• Enhancement Process
  – Why Enhance
  – Advantages and Disadvantages
  – Brine Components

• Early Post-Mortem Manipulation
  – Enhancement
  – Accelerated Chilling

• Current U of I research

• Conclusions and Recommendation
Animal Metabolism

• Ante-Mortem Metabolism
  – Aerobic or Anaerobic

• Aerobic (presence of oxygen)
  – Glycolysis
  – Glycogen to Pyruvate
  – Pyruvate enters the CAC = 32-36 ATP molecules
Animal Metabolism

• Anaerobic (lack of oxygen)
  – Glycolysis
  – Glycogen to Pyruvate
  – Pyruvate does not enter the CAC, instead converted to Lactic Acid
  – LA removed from tissue by circulatory system
  – Transported to liver
  – Through gluconeogenesis, LA metabolized into glucose via the Cori Cycle
Animal Metabolism

• Post-Mortem Metabolism
  – Glycolysis
  – Glycogen to Pyruvate
  – No Oxygen
  – Pyruvate to LA
  – No Circulatory System Present
  – LA and metabolic heat cannot be removed
  – ↑ LA causes ↓ in tissue pH (from 7.0 to ≈5.5)
  – Tissue temperature increases (≈5°)
  – Rate of pH decline and temperature play a major role in determining meat quality
Animal Metabolism
Enhancement

Why Enhance

• Advantages
  – Change of flavor profile
  – ↑ Juiciness
  – ↑ Tenderness
  – Improved Color
  – Improved Shelf Life
  – Improved Cooking attributes

• Disadvantages
  – Change of flavor profile
  – Increased Production Cost
  – Visual Problems
    • Striping
    • Surface exudate
Enhancement

• Brine Components for Fresh Product
  – Salt (typically .1 to .4% in final product)
    • Improves water holding capacity
  – Phosphates (up to .5% in final product)
    • Improves water holding capacity
  – Anti-Oxidants/Anti-Microbials (e.g. Lactates)
    • Improve shelf stability of the product
  – Flavorings
    • Change the flavor profile of the product
Early Post-Mortem Manipulation

• Enhancement provides many positives
• Under common practice, enhancement of product is used once the quality of the product has already been determined
• Limited improvement of poor quality product
Early Post-Mortem Manipulation

• However, if the product is manipulated before the ultimate quality is determined, some unique opportunities may exist
  – Early post-mortem enhancement
  – Accelerated chilling of product
Early Post-Mortem Manipulation Enhancement

• Early post-mortem enhancement with glycolytic inhibitors has been explored
• Jerez et al., 2003 used Sodium Citrate, Sodium Fluoride, Sodium Acetate, or Calcium Chloride in early post-mortem beef muscles
• Hot-boned muscles at 1h post-mortem and injected and tumbled with a 10% by wt solution
Early Post-Mortem Manipulation Enhancement

• Sodium Citrate and Sodium Fluoride yielded the highest pH and glycogen content for the beef muscles.
• Shows that the use of a glycolytic inhibitor, if applied early post-mortem, could be used to help yield higher quality product.
Early Post-Mortem Manipulation Enhancement

- Use of salt and phosphate early post-mortem
- Murphy and Zerby, 2004 in lamb carcasses
- Used different combinations of salt, phosphate, and dextrose
- Results indicated that some of the combinations of the different ingredients yielded higher ultimate pH, decreased cook loss, and increased tenderness
Early Post-Mortem Manipulation
Accelerated Chilling

- Accelerated chilling of the product allows for the possibility of improved product quality
- Honikel and Kim, 1986 showed that if the pH was less then 5.8 and the internal temperature was greater then 38 C, this would lead to protein denaturation
- Therefore, the accelerated chilling of the product may be able to help improve quality, by slowing the metabolic activity of the carcass
Early Post-Mortem Manipulation

<table>
<thead>
<tr>
<th>Authors</th>
<th>Test</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohene et. al., 2002</td>
<td>Intact Pork Sides, three chill treatment</td>
<td>Minimal improvements in quality from AC compared to CC</td>
</tr>
<tr>
<td>Ohene et. al., 2003</td>
<td>Intact Pork Sides, Halothane Carriers, two treatments</td>
<td>AC improved quality over the CC, in the LD but not the ham</td>
</tr>
<tr>
<td>Long and Tarrant, 1990</td>
<td>Pigs harvested in different seasons and treated to different cooling rates</td>
<td>Rapid Chilling reduced carcass temp and pH decline, decreased drip loss in ham</td>
</tr>
<tr>
<td>Crenwelge, et. al., 1984</td>
<td>Pigs harvested, sides ES, three chilling methods</td>
<td>The more rapid chilling increased muscle color for the ham, optimal temp reached faster in the rapid chilling methods</td>
</tr>
<tr>
<td>Weakley, et. al., 1986</td>
<td>Hot-bone loin, and placed in different cooling treatments</td>
<td>Rapid chilling caused darker muscle compared to normal chill</td>
</tr>
<tr>
<td>Seyfert, et. al., 2004</td>
<td>Beef Rounds, hot-boned knuckle, enhanced, MAP packaged</td>
<td>Hot-boning allowed for more rapid chilling, which resulted in darker color beef</td>
</tr>
<tr>
<td>King, et. al., 2003</td>
<td>Beef muscles were hot-boned and rapidly chilled, looked at different cooking methods also</td>
<td>The rapidly chilled sections had a faster temperature decline and numerically different rate of pH decline, resulted in cold shortening</td>
</tr>
</tbody>
</table>

**Conclusions**
Accelerated chilling can slow the rate of pH decline and increase the rate of chilling. This can cause an improvement in protein functionality leading to improved water holding capacity and improved color.
Early Post-Mortem Manipulation

• While some of the results may vary, it is possible to improve meat quality with accelerated chilling
• Results show that early post-mortem enhancement can improve meat quality
• The combination of early post-mortem enhancement and accelerated chilling has not been extensively explored
U of I Research
Accelerated Chilling

• Conventional Chill vs. Accelerated Chill
• 10 pigs (2 harvest days, 5 pigs per day)
  – Left Side Control
    • 24 hour at 4°C then ribbed
  – Right Side Test
    • Hot-Boned at 1 hour, Chilled 1 hour @ -27°C, stored 4°C for 23 hour
U of I Research
Accelerated Chilling

Temperature Decline
Accelerated vs Conventional Chill

Graph from 10 loins per treatment
### U of I Research

**Accelerated Chilling**

|                      | Control | Chilled | SE  | Prob>| T| |
|----------------------|---------|---------|-----|-----|---|
| 30 min               | 6.17    | 6.16    | 0.03| 0.5579|
| 1 h pH               | 5.98    | 5.83    | 0.12| 0.2581|
| 2 h pH               | 5.63    | 5.71    | 0.12| 0.5108|
| 3 h pH               | 5.43    | 5.60    | 0.06| 0.0142|
| 5 h pH               | 5.45    | 5.64    | 0.07| 0.0229|
| 6 h pH               | 5.48    | 5.61    | 0.07| 0.0766|
| 8 h pH               | 5.49    | 5.59    | 0.04| 0.0547|
| 20 h pH              | 5.49    | 5.53    | 0.03| 0.1479|
| Ult pH               | 5.48    | 5.49    | 0.03| 0.5397|
| Subjective Color     | 2.40    | 3.00    | 0.22| 0.0239|
| Hunter L*            | 56.56   | 53.70   | 1.01| 0.0193|
| % Drip Loss          | 5.20    | 4.35    | 0.52| 0.1405|
| 6-7 Day % Cook Loss  | 26.91   | 22.29   | 1.72| 0.0247|
| 6-7 Day Shears       | 5.50    | 5.22    | 0.40| 0.4992|

Significance $p<.05$

Trending $p<.10$
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Accelerated Chilling

• Higher pH at 3, 5, 6, and 8 hour post-mortem, coupled with reduced temperature resulted in improved quality.
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Enhancement and Accelerated Chill

• Enhancement in combination with accelerated chilling
  – 16 pigs total (2 harvest days, 8 pigs per day)
  – Treatments:
    • Conventional Chill Only (CC Only)
    • Conventional Chill with Enhancement (CCEN)
    • Accelerated Chill Only (AC Only)
    • Accelerated Chill with Enhancement (ACEN)
  – Brine Solution
    • .4% Salt, .4% Phos, 2.5% K-Lactate in final product
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Enhancement and Accelerated Chill

Pig 1

Left
CC Only
CC EN

Right
AC Only
AC EN

Pig 2

Left
CC EN
CC Only

Right
AC EN
AC Only
Enhancement and Accelerated Chill

• Each pig harvested according to University of Illinois SOP’s
• At 60 minute post-mortem, right side loin hot-boned
• Boneless loin:
  – Fat trimmed
  – Blade end removed
  – Cut in half (creating a loin section), weighed, assigned to pre-selected treatment
U of I Research
Enhancement and Accelerated Chill

• Treatments:
  – AC Only
  – AC EN (Enhanced First)
• Placed –27°C PG solution 1 hour
• Removed, stored at 4°C until 10 day post-mortem
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Enhancement and Accelerated Chill

• At 24 hour post-mortem
• Left Side fabricated
• Boneless Loin: Same process as right side
  – Trimmed of fat
  – Blade End removed
  – Cut in half (creating a loin section), weighed, and sorted into treatments
  – Stored at 4°C until 10 day post-mortem
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Enhancement and Accelerated Chill

• At 10 day post-mortem
• Loin Sections re-weighed
  – 10 day purge loss
• Sections faced off
• Allowed to bloom for 15 minute
• Subjective CMF and Striping Scores
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Enhancement and Accelerated Chill

• Once subjective scores were evaluated
• Serial Chops Cut (from center of loin)
  – Objective Color and pH
  – Taste Panel
  – Shear
  – Backup
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Enhancement and Accelerated Chill

• Objective Color and pH
U of I Research
Enhancement and Accelerated Chill

Water Holding Capacity

<table>
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<tr>
<th></th>
<th>AC</th>
<th>CC</th>
<th>p-value</th>
<th>EN</th>
<th>Non-EN</th>
<th>p-value</th>
<th>Interaction</th>
</tr>
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<tbody>
<tr>
<td>% 10 Day Purge</td>
<td>3.4</td>
<td>2.7</td>
<td>0.0479</td>
<td>2.6</td>
<td>3.6</td>
<td>0.0093</td>
<td>0.9804</td>
</tr>
<tr>
<td>% Cook Loss</td>
<td>19.7</td>
<td>22.5</td>
<td>0.0079</td>
<td>18.2</td>
<td>24.0</td>
<td>0.0009</td>
<td>0.7863</td>
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</table>

Significance is determined at p<.05
*****Scheffe adjustment
Subjective and Objective Scores

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<tr>
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<tbody>
<tr>
<td>Subjective Color</td>
<td>3.4</td>
<td>3.2</td>
<td>0.041</td>
<td>3.6</td>
<td>3.0</td>
<td>0.0002</td>
<td>0.1639</td>
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<tr>
<td>Subjective Firmness</td>
<td>3.4</td>
<td>3.3</td>
<td>0.576</td>
<td>3.6</td>
<td>3.1</td>
<td>0.0114</td>
<td>1.0000</td>
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</table>

Significance is determined at p<.05
*****Scheffe adjustment

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</thead>
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<tr>
<td>Minolta L*</td>
<td>47.99</td>
<td>50.48</td>
<td>0.0007</td>
<td>47.02</td>
<td>51.45</td>
<td>&lt;.0001</td>
<td>0.3092</td>
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<tr>
<td>Hunter L</td>
<td>52.20</td>
<td>54.38</td>
<td>0.0018</td>
<td>51.54</td>
<td>55.04</td>
<td>0.0002</td>
<td>0.0668</td>
</tr>
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Significance is determined at p<.05
*****Scheffe adjustment
U of I Research
Enhancement and Accelerated Chill

• Results indicate that accelerated chill improves pork quality over conventional chill
  – Improved Color and Water Holding Capacity
• Results also indicate that pork quality was increased by enhancement
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Enhancement and Accelerated Chill

• The combination of accelerated chilling and enhancement resulted in higher quality pork compared to conventional methods
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Glycolytic Inhibitors

• The effects of a glycolytic inhibitor in early post-mortem pork
• N=20
• Test to determine the use of a glycolytic inhibitor (sodium citrate) in early post-mortem muscle
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Glycolytic Inhibitors

• At approximately 1 h post-mortem, the loin was removed from both sides of the carcass, cut in half and assigned to the control treatment (salt and phos) or the test (salt, phos, NaC)
• Each section was vacuum packaged at 24h post-mortem and stored until 7 d post-mortem
At 7 d post-mortem evaluations were made on the loin sections. Chops cut from each loin section —GP —Shear and cook loss —MAP package At 14 d post-package, the MAP packaged chops were objectively evaluated for color
# U of I Research

**Glycolytic Inhibitors**

|                  | Control | Test  | Pr > |t| |
|------------------|---------|-------|------|---|
| Color            | 3.2     | 3.7   | 0.0104|
| Firmness         | 3.4     | 3.8   | 0.0611|
| **L**            | 49.80   | 46.98 | <.0001|
| Final pH         | 5.78    | 5.87  | 0.0012|
| % Cook Loss      | 25.48   | 18.00 | 0.0014|
| Shear Value      | 3.14    | 2.74  | 0.0374|
| 14 Day MAP package L* | 52.60 | 49.11 | <.0001|
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Glycolytic Inhibitors

• At 7 d post-mortem the test sections had a higher pH
• Sections that had been enhanced with NaC, had improved color scores (both objective and subjective), less cook loss, and improved shear force values
• At 14 d post-package (21 d p-m), the test chops were darker and more red (lower L* and higher a* values) than the controls
PORK QUALITY STANDARDS

COLOR - TEXTURE - EXUDATION

PSE  Pale pinkish gray, very soft and exudative. Undesirable appearance and shrinks excessively.


DFD  Dark purplish red, very firm and dry. Firm and sticky surface, high water-holding capacity.

COLOR STANDARDS

1.0  Pale pinkish gray to white
2.0  Grayish pink
3.0  Reddish pink
4.0  Dark reddish pink
5.0  Purplish red
6.0  Dark purplish red

MARBLING STANDARDS

1.0
2.0
3.0
4.0
5.0
6.0
10.0

For more information contact:
National Pork Producers Council
Conclusions and Recommendations

• The combination of early post-mortem enhancement and accelerated chilling has the potential to improve quality (patent pending).
• However, while this can be done at a research level, implementation at the plant level may require alterations in operations.
• Implementation at the plant level may be advantageous for consistent production of higher quality product.
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