Pork Quality: Current and Future Needs of Industry and Academia

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Basic and Applied Research

Louis Pasteur “fruits of the same tree”
Pork Quality: Current and Future Needs of Industry and Academia

Outline:

– Pork Quality - Brief History & Current Status

– Pork Quality - The Plausible Solutions (Quantitative & Molecular Genetics)

– Pork Quality – “Food Chain” Practical Solutions
Outline:

- Pork Quality - Brief History & Current Status
Pork Quality: Current and Future Needs of Industry and Academia

- **PSE: Identification & Description (1950s)**
  - Degenerative/myopathic condition
  - Early post-mortem changes
  - Ludvigsen, 1954; Henry et al., 1955; Briskey et al., 1959
  - Briskey, 1964: 88 pages/225 literature citation
• *Post-mortem Changes (1962-1966)*

  - pH decline (review by Briskey at al., 1966)
  - PSE association with glycolytic rate
  - Certain pigs were predisposed to rapid post-mortem glycolysis
Pork Quality: Current and Future Needs of Industry and Academia

• **Relationship of pH & Temperature (1961)**

  – PSE = pH and temperature relationship (Wismer-Pedersen & Briskey, 1961)

  – Importance of chilling (color & WHC)
## Overview of Issues in PSE/RSE Meat Quality: Current Problems and Future Directions

### Packer Costs Associated with Quality Problems

<table>
<thead>
<tr>
<th>Packer Defect</th>
<th>Cost $/Head</th>
<th>Cost Controlled by Farmer $/Head¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leanness problems:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backfat thickness</td>
<td>2.80</td>
<td>100</td>
</tr>
<tr>
<td>Degree of ham and butt trimming</td>
<td>1.87</td>
<td>100</td>
</tr>
<tr>
<td>Excessive seam fat</td>
<td>.63</td>
<td>100</td>
</tr>
<tr>
<td>Bellies too fat or too thin</td>
<td>.14</td>
<td>100</td>
</tr>
<tr>
<td>Weight problems</td>
<td>.88</td>
<td>100</td>
</tr>
<tr>
<td><strong>Carcass problems:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcass condemnations</td>
<td>1.00</td>
<td>75</td>
</tr>
<tr>
<td>Abscesses</td>
<td>.47</td>
<td>100</td>
</tr>
<tr>
<td>Bruises</td>
<td>.08</td>
<td>75</td>
</tr>
<tr>
<td>Skin problems</td>
<td>.01</td>
<td>75</td>
</tr>
<tr>
<td>Arthritis</td>
<td>.08</td>
<td>100</td>
</tr>
<tr>
<td>Other</td>
<td>1.29</td>
<td>0</td>
</tr>
<tr>
<td><strong>PSE/color problems:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>.27</td>
<td>75</td>
</tr>
<tr>
<td>Pale, soft, watery</td>
<td>.34</td>
<td>75</td>
</tr>
<tr>
<td>Dark, firm, dry</td>
<td>.01</td>
<td>75</td>
</tr>
<tr>
<td><strong>Total packer costs</strong></td>
<td>10.08</td>
<td>8.15</td>
</tr>
</tbody>
</table>

¹Calculated by multiplying cost per head and percent of cost controlled by farmer.

Source: National Pork Producers Council, 1994
Vertical Coordination in the Pork and Broiler Industries, Economic Research Service/USDA, April 1999
Surveys of Incidence (1960s -1990s)

- **1963**: 18% hams were PSE (daily range: 0%-to-70%; Forrest et al., 1963)
- **1992**: 16% loins were PSE (Pork supply in the U.S.A.; Kauffman et al., 1992)
- **1996**: 9.8% loins were PSE (Survey of U.S. Commerical Plants; Scheller et al., 1996)
  - RFN (Minolta L* < 50, pHu > 5.5): 68.6% to 66.5%
  - RSE (Minolta L* < 50, pHu < 5.5): 18.6% to 21.5%
  - PSE (Minolta L* > 50): 9.8%
  - DFD (pHu > 6.2): 0.5% to 1.1%

Incidence of PSE is decreasing, but…
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• Current Pork Quality Challenges...

  – PSE - still persists, but at lower incidence

  – RSE – emerged and still considered as a meat quality problem (whole muscle firmness)

  – Variation/uniformity

  – Mechanisms of drip loss – not fully understood

  – Ultimate pH/Relationship to “eating quality” – within and between muscles

  – pH decline/Relationship to “eating quality” – within and between muscles
Muscle Foods System

PIC USA • The better pork people™ • PIC USA • The better pork people™ • PIC USA • The better pork people™ • PIC USA • The better pork people™
Muscle Foods System

Conversion of Muscle to Meat
Muscle Foods System
Muscle Foods System

Information Feedback

Muscle Differentiation and Growth
Welfare/Stress Physiology
Developmental (Muscle) Biology
Conversion of Muscle to Meat

Functional Genomics & Proteomics

Muscle Foods
**Developmental Biology**
Steps Involved in Determination of Lineage and Differentiation to Cell Types

Duprey and Lesens, 1994
Muscle Fiber Types

- MHC-Type I = SO (slow contracting, oxidative, “red”)
- MHC-Type IIa & IIx = FOG (fast contracting, oxidative, glycolytic, “white”)
- MHC-Type IIB = FG (fast contracting, glycolytic, “white”)
Distribution Patterns of MHC in Porcine Muscle

Greaser et al, ICoMST, 2000
Differences in MyosinHC Isoform Proportion of Porcine M. Longissimus Thoracis

RT-PCR of RNA

Tonebe et al, 1999
Transcriptional and Translational Regulation of Myosin Expression in Skeletal Muscle

Muscle Growth Factors

Transcriptional Control

DNA

Activity Factors

Work

Translational Control

mRNA

1

2

3
**Developmental (Muscle) Biology**

- Understand protein deposition (MHCs) in fast growing pigs and its implication for meat quality
- Elucidate the role of satellite cell proliferation in muscle growth and meat quality
- “Optimize” collagen type and structure of porcine muscle in relation to physiological age and function (endomysium and perimysium)
- Muscle and liver glycogen storage mechanisms and their interaction
Muscle Foods System

Information Feedback

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Muscle Foods
General types of biological responses available to cope with stress

- **Behavior**
- **Immune system**
- **Neuroendocrine system**
- **Autonomic nervous system**
Why reduce stress responsiveness?

- Increased production (better ADG and FC)
- Improved reproductive performance
- Increased disease resistance
- Better meat quality
- Improvement of animal welfare
# Stress Hormones and Meat Quality

*(urine-based research)*

<table>
<thead>
<tr>
<th></th>
<th>AD</th>
<th>NA</th>
<th>pH24</th>
<th>Lean%</th>
<th>IMF%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortisol</td>
<td>.42</td>
<td>.15</td>
<td>.04</td>
<td>-.24</td>
<td>.02</td>
</tr>
<tr>
<td>Adrenaline</td>
<td>.55</td>
<td>.27</td>
<td>-.29</td>
<td>.07</td>
<td></td>
</tr>
<tr>
<td>Noradrenaline</td>
<td>.24</td>
<td>-.07</td>
<td>-.07</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**F2 Duroc x Large White (n=312)**

**** Significance

*Fourry and Mormede, 2002*
Pork Quality: Current and Future Needs of Industry and Academia

Welfare/Stress Physiology R&E

- Understand “Biological Cost of Stress” (i.e., stress vs. distress)
- Develop methods to measure distress under commercial conditions (farm-to-processing facility);
- Develop “Selective Breeding” to modify stress responsiveness of pigs
- Quantify” the effects of human-animal interactions on animal welfare/stress/productivity
Muscle Foods System

Information Feedback

- Muscle Differentiation and Growth
- Welfare/Stress Physiology
- Developmental (Muscle) Biology
- Conversion of Muscle to Meat

Functional Genomics & Proteomics

Muscle Foods
Relationship Between Rate of Post-Mortem pH Decline and Meat Quality in Pigs

Sellier and Monin, 1994
Traditional pH decline in pork???

Early Postmortem Decline
(Pork)

<table>
<thead>
<tr>
<th>pH Value</th>
<th>Time Postmortem (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longissimus Dorsi (LD)</td>
<td>0 3 6 9 12 15 18 21 24</td>
</tr>
<tr>
<td>Semimembranosus (SM)</td>
<td>0 3 6 9 12 15 18 21 24</td>
</tr>
<tr>
<td>Psoas Major (PM)</td>
<td>0 3 6 9 12 15 18 21 24</td>
</tr>
</tbody>
</table>

Early Postmortem Decline
(Bovine)

<table>
<thead>
<tr>
<th>pH Value</th>
<th>Time Postmortem (hrs)</th>
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</thead>
<tbody>
<tr>
<td>Longissimus</td>
<td>0 3 6 9 12 15 18 21 24</td>
</tr>
<tr>
<td>Psoas Major</td>
<td>0 3 6 9 12 15 18 21 24</td>
</tr>
</tbody>
</table>

Postmortem proteolysis

Proteins of Interest
– Desmin
– Titin
– Nebulin
– Troponin T

(Robson, et al. 1981. RMC Proceedings. 5-11.)

(Goll, et al. 1999. The Calpain System in Muscle Tissue IN: Pharmacology and Toxicology of Calcium-Dependent Protease. P126-160.)
Ultrastructural Changes and Water Holding Capacity

Costameric Degradation
(Taylor et al., 1995. J. Anim. Sci. 73:1351-1367.)

Intermyofibril Degradation
(Taylor et al., 1995. J. Anim. Sci. 73:1351-1367.)
Relationship between Desmin Degradation and Drip Loss


\[ \text{Drip Loss (\%)} \]

\[ \begin{array}{ccc}
24 & 96 \\
LD & a & a \\
SM & a & b \\
PM & a & b \\
\end{array} \]

\text{Storage Time (hrs)}

\( a, b \) Means within the same time point postmortem with different superscripts were significantly different (P<.05) at each time point.
Degradation of Desmin Occurs Early Postmortem

6 hours postmortem

- a,b Means within the same time point postmortem with different superscripts were significantly different (P < 0.05) at each time point.

![Graph showing Desmin Degradation Ratio over time](image)
Muscle Foods System

Information Feedback

Muscle Differentiation and Growth
Welfare/Stress Physiology
Developmental (Muscle) Biology
Conversion of Muscle to Meat
Raw/Fresh Retail, Food Service & Export

Functional Genomics & Proteomics

Muscle Foods
**Pork Quality:**
Current and Future Needs of Industry and Academia

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**Raw Material Quality R&D**

- Develop “muscle-to-meat” kinetic models to predict meat quality
- Understand factors underlying formation of ultimate pH
- Better understand the economic value of meat quality traits in the supply chain
Muscle Foods System

Information Feedback

Muscle Differentiation and Growth
Welfare/Stress Physiology

Developmental (Muscle) Biology

Conversion of Muscle to Meat

Functional Genomics & Proteomics

Muscle Foods
Marker Assisted Selection

- Genome Scans & Candidate Genes
- Functional Genomics
- Proteomics
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hal-1843® gene</td>
<td>Malignant hyperthermia – porcine stress syndrome</td>
<td>Fuji et al. (1991)</td>
</tr>
<tr>
<td>RN gene</td>
<td>Acid pork (Hampshire)</td>
<td>Milan et al. (2000)</td>
</tr>
<tr>
<td>MC4R</td>
<td>Appetite, fatness and homogeneity of pig carcasses</td>
<td>Kim et al. (2000)</td>
</tr>
<tr>
<td>BETTERgen™ / IGF2</td>
<td>Lean meat content of muscular breeds</td>
<td>Nezer et al. (1999), Jeon et al. (1999)</td>
</tr>
<tr>
<td>FABPs</td>
<td>Level of intramuscular fat (Duroc)</td>
<td>Gerbens et al. (1997, 1998)</td>
</tr>
<tr>
<td>Unidentified (QTL)</td>
<td>Intramuscular fat and backfat thickness (Iberian pig)</td>
<td>Ovilo et al. (2000)</td>
</tr>
<tr>
<td>Unidentified (QTL)</td>
<td>Level of intramuscular fat (Meishan)</td>
<td>Janss et al. (1994, 1997)</td>
</tr>
<tr>
<td>Unidentified (QTL)</td>
<td>Level of intramuscular fat (Duroc)</td>
<td>Monin et al. (1998)</td>
</tr>
<tr>
<td>Calpain</td>
<td>Level of calpain – pork tenderness</td>
<td>Parr et al. (1999)</td>
</tr>
<tr>
<td>MyoG (myf4)</td>
<td>Muscle yield</td>
<td>Soumillion et al. (1997)</td>
</tr>
<tr>
<td>MyHC</td>
<td>Fiber type – pork tenderness</td>
<td>Beuzen et al. (2000)</td>
</tr>
<tr>
<td>CAST</td>
<td>Level of calpastatin – pork tenderness</td>
<td>Ernst et al. (1998)</td>
</tr>
<tr>
<td>Unidentified (QTL)</td>
<td>Level of androsterone – boar taint</td>
<td>Fouilloux et al. (1997)</td>
</tr>
</tbody>
</table>
Molecular Genetics - Markers

- “Turbo charging” the Quantitative Engine
- Faster genetic improvement
- Differentiate products
Conclusions:

**Optimising Genetics**

- Better understanding of economic value of muscle quality traits

- Several gene markers affecting muscle quality are being discovered and used in breeding programs

- Faster, lower cost implementation of genotyping

- Specialized (customized) lines are being developed
Research Priorities for Pork Industry and Academia

1. Greater understanding of perimortem and early postmortem muscle biology

2. Better understanding of the economic value of meat quality attributes

3. Precise breeding/production systems should be established to insure acceptable animal/stress welfare physiological behavior

4. Implement MQ focused statistical process procedures to ensure sustainability of the production systems