“The Connection” Between Pig Responses to Stress and Pork Quality


PIC/ABS, Colorado State University, ELANCO, Hormel Foods Corp.

SYNOPSIS

1. Defining ‘Stress/Welfare’ Physiology: Science and Practical Considerations
2. Defining Pork Quality: Science and Practical Considerations
3. “The Connection”: Practical Examples
4. Conclusions
...We (Animal Agriculture Managers) Demand Simple Solutions to Solve Complex (Biological) Issues...

... We (Biologists) Understand those Simple Solutions, (Most Likely), Do Not Exist...
1. Defining ‘Stress/Welfare’ Physiology: Science and Practical Considerations

2. Defining Pork Quality: Science and Practical Considerations

3. “The Connection”: Practical Examples

4. Conclusions
Definition of Stress:

“Biological Response Elicited When an Individual Perceives a Threat to its Homeostasis”

*Threat* = “stressor”

When the stress response threatens the animal well-being, then the animal experiences “DISTRESS” (Moberg, 2000)

(One of the) key challenges is to determine when STRESS becomes DISTRESS
Defining stress:

Inherent difficulties exist in defining precisely what is meant by welfare or well-being and how it should be measured

- Defining “suffering” in physiological/behavioral terms is unrealistic” (Barnard & Hurst, 1996)
- Unlike most diseases, stress has no defined aetiology or prognosis (Moberg, 2000)
- Links between animal welfare and stress are unclear (Mench, 2000; Moberg, 2000)
- The very act of monitoring (physiological responses to stress) is stressful, confounding our interpretation of results (Cook at al., 2000)
- Further complication is inter-animal variability in the stress response (Moberg, 1985)
- There are variety of events that mould the stress response (Moberg, 2000)
- “The fact that different disease patterns emerge in animals experiencing the same stress is being attributed to differences in stress responses” (Henry, 1992)
Four General Biological “Defense” Responses to Cope with Stress

**Behavior**

Stress avoidance; Positive adapting/coping

**Neuroendocrine system**

Hormone signaling involving:

- Hypothalamus
- Pituitary gland
- Peripheral body system

**Autonomic nervous system**

*Flight or fight’* (Cannon, 1929)

**Immune system**
How to measure stress?

Physiological indices

Blood hormone concentrations:
- Adrenaline
- Noradrenaline
- Corticotropin-releasing factor
- Adrenocorticotropic hormone
- Glucocorticoids (e.g. cortisol)
- Prolactin

Blood metabolite concentrations:
- Glucose
- Lactic acid
- Free fatty acids
- β-hydroxybutyrate
- Creatine kinase (CPK)

Other variables:
- Heart rate
- Breathing (rate and depth)
- Packed cell volume
- Sweat production
- Muscle tremor
- Body temperature
- Plasma α-acid glycoprotein levels
- Blood leukocyte levels
- Cellular immune responses
- Humoral immune response

Matteri et al., 2000
How to measure stress?

Behavioral indices

**Vocalization:**
- Whimpers, howls, growls, screams, grunts, moans, squeaks, squeals, chirps, silent

**Locomotion:**
- Reluctant to move, awkward, shuffles, staggers, falls, stands up/lies down repeatedly, circles, escape/avoidance movements, pacing, restless, writhing

**Posture:**
- Cowers, crouches, huddled, hiding, lying (legs extended, all or some legs tucked in), standing (on all or not all legs, rigid, head against wall, drooping)

**Temperament:**
- withdrawn, depressed, quiet, docile, miserable, agitated, anxious, frightened, terrified, aggressive

*Matteri at al., 2000*
Pig Stress/Welfare and Meat Quality

1. Evaluation of situation (pig stress/welfare)
   - Action

2. Behavioral and physiological response
   - Muscle metabolism

- Rearing conditions
- Actual stress situation
- Genetics

Pork Quality
**Force** = Cross Section of Contractile Apparatus

**Power** = Speed of Contraction x Mass

GLYCOGEN = MUSCLE Fuel

This energy is rapidly put to use when the muscle needs to contract

Energy is derived via 2 metabolic pathways:
1. **Aerobic** (*oxygen present*)
2. **Anaerobic** (*no oxygen available* = Lactic Acid metabolism)
1. Defining ‘Stress/Welfare’ Physiology: Science and Practical Considerations

2. Defining Pork Quality: Science and Practical Considerations

3. “The Connection”: Practical Examples

4. Conclusions
Pork Quality Attributes

**Meat (Instrumental) Quality**
- pH45-min post-mortem
- pHu – 24 hours post-mortem
- Color
- Drip Loss
- Purge Loss
- Water-holding Capacity
- Water-binding Capacity
- Firmness of Lean
- Texture/Tenderness/Juiciness
- Shear Force
- Firmness/Color of Fat

**Eating (Sensory) Quality**
- Tenderness
- Juiciness
- Flavor/Aroma
- Off-flavor
- Fat content/FA composition
Post-Mortem Conversion of Muscle to Meat: 
*M. Longissimus* (Loin) pH Decline Curves

- A; drip = 1.85%
- B; drip = 3.43%
- C; drip = 2.54%
- D; drip = 1.56%

ATP down

LAC up

GLYCOGEN=MUSCLE Fuel
Post-Mortem Conversion of Muscle to Meat: 
*M. Longissimus (Loin) pH Decline Curves*

- **A; drip = 1.85%**
- **B; drip = 3.43%**
- **C; drip = 2.54%**
- **D; drip = 1.56%**

Graph showing pH decline curves over time postmortem.
Relationship Between % Drip Loss and pH 24-hour PM (E. & S. Lonergan, ISU)

\[ y = 650609e^{-3.0479x} \quad R^2 = 0.5549 \]

\[ y = 226186e^{-2.849x} \quad R^2 = 0.5886 \]

\[ y = 372724e^{-2.8673x} \quad R^2 = 0.6016 \]

pHu = 5.85-6.00
### Heritability Estimates for Meat Quality Characteristics

<table>
<thead>
<tr>
<th>Trait</th>
<th>Estimated Heritability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate pH (Initial pH)</td>
<td>.31 (.26)</td>
</tr>
<tr>
<td>Color (reflectance)</td>
<td>.37 (.25)</td>
</tr>
<tr>
<td>Drip Loss %</td>
<td>.18 (.28)</td>
</tr>
<tr>
<td>Intramuscular Fat Percent</td>
<td>.53</td>
</tr>
<tr>
<td>Tenderness (taste panel)</td>
<td>.27</td>
</tr>
<tr>
<td>Tenderness (shear force)</td>
<td>.21</td>
</tr>
<tr>
<td>Juiciness (taste panel)</td>
<td>.06</td>
</tr>
</tbody>
</table>
1. Defining ‘Stress/Welfare’ Physiology: Science and Practical Considerations

2. Defining Pork Quality: Science and Practical Considerations

3. “The Connection”: 4 Practical Examples

4. Conclusions
EXAMPLE #1:

“Critical Pre and Post-slaughter Factors in Relation to Pork Quality”

Ellen Hambrecht
Ph.D Thesis, 2004

Chapter 3:
Rapid chilling cannot prevent inferior pork quality caused by high preslaughter stress...

Chapter 4:
Preslaughter stress and muscle energy (GLYCOGEN STORES) largely determine pork quality...
“Critical Pre and Post-slaughter Factors in Relation to Pork Quality”

![Graph showing the relationship between glycolytic potential and 24-hour drip loss, with high and minimal stress regions identified.](image-url)
Figure 3. Percentage of change in pork quality attributes between pre-slaughter stress levels (minimal vs. high) and chilling method (conventional vs. rapid). Asterisks associated with a bar indicate differences ($P < 0.05$) between stress levels or chilling methods (DL = drip loss percentage after storage for either 24 or 48 h; FPW = filter-paper measured moisture; EC = electrical conductivity; and FOP = fiber optic-measured light scattering. Also, $L^*$ = a measure of lightness; $a^*$ = a measure of redness; and $b^*$ = a measure of yellowness).
EXAMPLE #2:

The effects of pre-slaughter pig management from the farm to the processing plant on pork quality


*Department of Animal Sciences, Colorado State University, Fort Collins, CO 80523, †Elanco Animal Health, Greenfield, IN and ‡PIC, Hendersonville, TN
Pig Blood Lactate and the Marketing Process

Range in [LAC] 1.2 mM - 16.9 mM

The effects of pre-slaughter pig management from the farm to the processing plant on pork quality, Edwards at al, 2009
Pig Blood Lactate and the Marketing Process

 Increased [LAC] gives Improved pork quality 
   \textit{Edwards et al., 2009} 

 Increased [LAC] gives Reduced pork quality 
   \textit{Hambrecht et al., 2004} 

The effects of pre-slaughter pig management from the farm to the processing plant on pork quality, Edwards at al, 2009
EXAMPLE #3

Pigs Aggressive Temperament Affects Pre-slaughter Mixing Aggression, Stress and Meat quality

1SAC Edinburgh UK; 2PIC Germany, 3PIC UK, 4 FBN Dummerstorf Germany; 6 INRA France

Identification of Genes Involved in the Genetic Control of Aggressiveness, Stress Responsiveness, Pork Quality and their Interactions

1Research Institute for the Biology of Farm Animals (FBN), Dummerstorf, Germany; 2Sustainable Livestock Systems, SAC, Edinburgh, UK; 3PIC UK, Oxfordshire, UK; 4 Université de Bordeaux 2, PsyNuGen, INRA UMR1286, Bordeaux, France; 5PIC Deutschland GmbH, Schleswig, Germany
Experiment: 3 parts

560 ♂ and ♀ pigs in 8 batches of ~70

1. Aggressiveness
2. Pre-transport mixing
3. Slaughter
1. Aggressiveness

At ~10 weeks of age, mix pigs into groups of balanced composition (2+2+2+2=8)

Count skin lesions (change pre-post mixing) and classify pigs as High (H) or Low (L) aggressiveness
2. Pre-transport mixing

~27 weeks old, count skin lesions

8 batches:
• 4 ‘controlled mixing’ batches: Mixed onto truck on the basis of aggressiveness (4+4 = 8)
  – High + High (HH)
  – High + Low (HL)
  – Low + Low (LL)
  – Unmixed (U) onto truck
  – No mixing at lairage

• 4 ‘uncontrolled mixing’ batches: commercial-style mixing at transport and again at lairage
3. Slaughter

- Carcass **skin lesion** count
- Blood sample for stress measures:
  - Cortisol
  - Creatine Kinase (CPK)
  - Glucose
  - **Lactate**
- **Meat quality measures** (Loin muscle)
  - \textit{pH at 3, 6 and 24 hrs}
  - Drip loss (to 48hr)
  - Colour (light-, red-, and yellow-ness)
Results: controlled mixing

Cortisol tended to be higher in HH pigs (F=2.49, p=0.061)

Skin lesions were associated with higher cortisol (front lesions, $r^2=7.7\%$)
Results: controlled mixing

Loin muscle pH at 24hrs was higher in HH groups

- Higher skin lesions were also associated with *higher pH 24* ($r^2=5.1\%, p=0.004$)
EXAMPLE #4:

RELATIONSHIPS BETWEEN PROTEIN EXPRESSION AND MEAT QUALITY IN PIGS: INFLUENCES OF REARING ENVIRONMENT AND GENETIC BACKGROUND

Kwasiborski¹ A., Sayd¹ T., Chambon¹ C., Lhoutellier-Santé¹ V., Rocha² D. and Terlouw¹ C.

1 QuAPA, INRA de Theix, 63122 St-Genès-Champanelle, France  2 Genus-plc, Department of Pathology, University of Cambridge, Tennis Court Road, Cambridge CB2 1QP, United Kingdom
CONCLUSIONS

Relationships between protein expression and meat quality depended on pig gender, breed and rearing method.

Outdoor pigs:
Myoglobin expression explained 57% of $L^*$ (meat lightness) variability and ultimate $pH$ improved the model by 14%.

Indoor pigs:
No correlation between $L^*$ and myoglobin expression was found. 56% of the $L^*$ variability was explained by ultimate $pH$.

Kwasiborski et al, 2008
“The Connection” Between Pig Responses to Stress and Pork Quality

CONCLUSIONS

“The impact of stress on animal welfare is too important to ignore

…we must strive to develop an understanding of the biological response to stress”…

(Moberg, 2000)
“The Connection” Between Pig Responses to Stress and Pork Quality

Conclusions/Next Steps:
Understand “Biological Cost of Stress” (i.e., stress vs. distress)
Fully develop methods to measure distress under commercial conditions (farm-to-processing facility) and its relationship to MEAT QUALITY