Have we underestimated the impact of pre-slaughter stress on meat quality in ruminants?

Drewe Ferguson and Robyn Warner
Overview

• General impact of pre-slaughter stress
  • Animal
  • Muscle/meat

• Specific effects of some pre-slaughter factors

• Strategies to minimise the impact of pre-slaughter stress
Pre-slaughter stress

• Highly likely there will be losses in product quantity and quality during transfer from farm to abattoir

• Magnitude will depend on:
  • type, intensity and duration of stressors
  • susceptibility of the animal to stress

• Potential impacts
  • Carcass weight and yield
  • Visual appeal
  • Eating quality
  • Animal welfare
Variation between slaughter groups

- Young cattle
- 9 farms within 370 km of the abattoir
- Pasture finished + supplements
- Consigned direct to the abattoir
- Overnight lairage
- Electrical stim.
- Striploins aged 14 day

What is the origin or basis for this variation in eating quality?
Variation between slaughter groups

- On-farm factors
  - Genetics
  - Nutrition

- Pre-slaughter

- Post-slaughter
  - $pH_{3h}$ 5.9 - 6.2
  - $pH_u$ 5.4 - 5.6

$pH_{3h} = 6.6$ – cold shortening
Variation in LTL shear force (Johnston et al 2001)

N = 2279 ; 68 slaughter groups

<table>
<thead>
<tr>
<th>Slaughter group variables</th>
<th>% Variance LTL shear force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slaughter group</td>
<td>17.8</td>
</tr>
<tr>
<td>Slaughter weight and finishing system (pasture or feedlot)</td>
<td>1.4</td>
</tr>
<tr>
<td>Electrical stimulation (LV or HV)</td>
<td>1.1</td>
</tr>
<tr>
<td>Slaughter date</td>
<td>15.3</td>
</tr>
</tbody>
</table>
Unexplained variation in meat quality between slaughter groups

- Pre-slaughter practices and handling of livestock
  - May account for a significant proportion of this variation
  - Independently or through interactions with on-farm or post-slaughter factors
Pre-slaughter stressors

- Mustering
- Loading & unloading
- Transport
- Marketing
- Abattoir lairage & handling
Impact of pre-slaughter stress

Animal

1. Fear and distress
2. Hydration and metabolic challenges
3. Increased physical demands
4. Reduced physical integrity
1. Fear and distress

- Profound change in behaviour and physiology
- Increased flight response and vigilance
  - Muscle trauma through impact (bruising)
  - ↑ utilisation of energy substrates
- Sympatho-adrenal (SA) activation
  - ↑ adrenaline and noreadrenaline
  - ↑ hepatic gluconeogenesis
  - ↑ lipolysis
  - ↑ muscle glycogenolysis
- Hypothalmo-pituitary-adrenal (HPA) axis activation
  - ↑ Cortisol
  - ↑ hepatic gluconeogenesis
  - Amplifies the actions of catecholamines
Livestock adapt to fearful challenges

(Pettiford et al. 2008)
Direct effects of adrenaline

Pre-slaughter adrenaline injection or infusion

- Large increase in muscle glycogenolytic rate in cattle (Tarrant 1989)
- Small transient effect on calpain activity post-mortem in pigs (Sensky et al 1996)
- No effect (exercise 5 min+ adrenaline injection) on SM shear force in lambs (Bond et al 2004)
Catecholamine-mediated depletion of glycogen – muscle dependent

- Effect dependent on interaction between muscle activity and fibre type (Richter et al 1982)

- Dark Colour
- Increased Toughness (pHu 5.9 - 6.2)
- Higher WHC
- Shorter shelf life
Direct effect of cortisol (HPA axis)

Sheep given ACTH challenge
(Glucocorticoids ➔ stimulate proteolysis)

- No effect on glycolytic rate, pHu, shear force or ageing rate

(Ferguson et al *in preparation*)
2. Metabolic and hydration challenges

- Food and water (sometimes) deprivation (≤ 48 h)
- Ruminants can generally tolerate periods of food and water deprivation better than monogastrics (e.g. Cole et al 1995)
Pre-slaughter water deprivation
(Jacob et al 2006)

- Aust. sheep research
  50% lambs were dehydrated at slaughter
  - Urine SG > 1.045
3. Increased physical demands

- Glycogen loss is less evident during low intensity muscular activity.

- Eg. maintaining posture and balance during transport

(Knowles et al 1999)
4. Reduced physical integrity

- Broken limbs and trauma
- Bruising
- Hypo- or hyperthermia
- Death
Pre-slaughter Factors
Pre-slaughter Factors

• Lairage duration (cattle)

• Marketing method (cattle)

• Animal handling in the immediate pre-slaughter period (cattle and sheep)
Lairage duration in feedlot cattle
3 h v 18 h lairage

<table>
<thead>
<tr>
<th>Trait</th>
<th>Study 1 (n=90)</th>
<th>Study 2 (n=146)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 h</td>
<td>18 h</td>
</tr>
<tr>
<td>Shear force (N)</td>
<td>46.1</td>
<td>49.1</td>
</tr>
<tr>
<td>pHu</td>
<td>5.4</td>
<td>5.4</td>
</tr>
<tr>
<td>Glycogen (umol/g)</td>
<td>95.3</td>
<td>92.1</td>
</tr>
<tr>
<td>MSA CMQ4*</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>

( Ferguson et al 2007; Petherick et al in prep.)

No significant differences
### Lairage duration in sheep (Jacob et al 2005)

<table>
<thead>
<tr>
<th></th>
<th>Lambs</th>
<th></th>
<th></th>
<th>Ewes</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arrival</td>
<td>Day 1</td>
<td>Day 2</td>
<td>Arrival</td>
<td>Day 1</td>
<td>Day 2</td>
</tr>
<tr>
<td>pHu</td>
<td>5.75&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.93&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.87&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.86&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tenderness</td>
<td>62.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>67.3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>61.3&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>58.6&lt;sup&gt;d&lt;/sup&gt;</td>
<td>55.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>56.5&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

No primary effect of lairage duration on sensory tenderness score
Marketing method

• Auction or saleyard selling still popular in some countries

• Animals destined for slaughter are exposed to extra handling, transport and increased food deprivation

• At the time Meat Standards Australia excluded cattle from saleyards
Experimental design

Nine Farms
28 - 30 head

Half consigned to the saleyard
Day 1

Transported to the abattoir
Day 2

Half consigned to the abattoir
Day 1

Abattoir
Direct - slaughtered Day 2
Saleyard - slaughtered Day 3

Saleyard
MSA consumer panel score (CMQ4)

Elec. stim. failure

Direct Consignment
Saleyard

Farm
1 2 3 4 5 6 7 8 9
Animal handling in the immediate pre-slaughter period
Pre-slaughter handling (Hemsworth et al 2008)

Observed cattle and sheep from lairage to slaughter area

- 2 sheep and 2 cattle abattoirs
- 200 animals/abattoir
- Plasma cortisol

<table>
<thead>
<tr>
<th>Sheep abattoirs</th>
<th>Cattle abattoirs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of day</td>
<td>Vocalisations</td>
</tr>
<tr>
<td>Abattoir</td>
<td>Abattoir</td>
</tr>
<tr>
<td>Head position</td>
<td>Head position</td>
</tr>
<tr>
<td>Auditory interactions</td>
<td>Auditory interactions</td>
</tr>
<tr>
<td>Prods received</td>
<td>Prods received</td>
</tr>
</tbody>
</table>

% var. plasma cortisol
- Sheep abattoirs: 21%
- Cattle abattoirs: 44%
Swim-washing lambs

- Toughening effect independent of pH_u after swim-washing

Geesink et al (2001)
- Swim-washing 3 h before slaughter
- pH_u >5.8 32.5 % washed vs. 15% control
Exercise stress in lambs (Warner et al 2005)

15 min running just prior to slaughter
- exercised until evidence of fatigue
- + or – LV electrical stimulation (post-slaughter)

<table>
<thead>
<tr>
<th></th>
<th>No exercise (n = 24)</th>
<th>Exercise (n = 24)</th>
<th>Sig. terms</th>
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<tbody>
<tr>
<td>pH_{0.5h}</td>
<td>6.73</td>
<td>6.40</td>
<td>6.68</td>
</tr>
<tr>
<td>pH slope</td>
<td>-0.12</td>
<td>-0.09</td>
<td>-0.09</td>
</tr>
<tr>
<td>pH_{u}</td>
<td>5.58</td>
<td>5.56</td>
<td>5.92</td>
</tr>
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Exercise stress in lambs (Warner et al 2005)

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<tr>
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<th>No exercise (n = 24)</th>
<th>Exercise (n = 24)</th>
<th>Sig. terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear force (1day)</td>
<td>4.5</td>
<td>4.3</td>
<td>3.8</td>
</tr>
<tr>
<td>Shear force (5days)</td>
<td>2.4</td>
<td>2.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Sensory tenderness</td>
<td>62.4</td>
<td>59.7</td>
<td>68.1</td>
</tr>
</tbody>
</table>

Improvement due to exercise was probably mediated by differences in pHu
Not clear why
Electric prodding (Warner et al. 2007)

• 6-8 times 15 min before slaughter
• 84 cattle (3 replicates)
• Treatment allocated to groups of 4 cattle/replicate
## Electric prodding (Warner et al. 2007)

<table>
<thead>
<tr>
<th></th>
<th>No electric prodder</th>
<th>Electric prodder (6-8 times)</th>
<th>Signif.</th>
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</thead>
<tbody>
<tr>
<td>Plasma lactate</td>
<td>4.29</td>
<td>7.12</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>$pH_1h$</td>
<td>6.33</td>
<td>6.29</td>
<td>ns</td>
</tr>
<tr>
<td>Muscle temp. 1h</td>
<td>37.7</td>
<td>37.7</td>
<td>ns</td>
</tr>
<tr>
<td>$pH_u$</td>
<td>5.46</td>
<td>5.38</td>
<td>ns</td>
</tr>
<tr>
<td>Purge % (21 days)</td>
<td>3.5</td>
<td>5.4</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>Shear force (2 days)</td>
<td>91.1</td>
<td>89.2</td>
<td>ns</td>
</tr>
<tr>
<td>Shear force (21 days)</td>
<td>47.0</td>
<td>51.0</td>
<td>ns</td>
</tr>
<tr>
<td>MSA CMQ4 score</td>
<td>59.6</td>
<td>55.6</td>
<td>P&lt;0.05</td>
</tr>
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Management and Control of Pre-slaughter Stress
Pre-slaughter supplements


• Magnesium
  • Reduces neuromuscular stimulation as it is Ca$^{2+}$ antagonist (Hagiwara et al 1973)
  • Extensively studied in pigs

• Tryptophan
  • Precursor for serotonin (eg. arousal, aggression)
  • Studied in pigs but not ruminants

• Electrolytes
  • Combination of salts and carbohydrates
  • Offered pre-transport or pre-slaughter
Pre-slaughter supplements – Magnesium oxide (Gardner et al 2001)

MgO reduced glycogen loss in Merino lambs

Recommended - 1% for 4 days pre-slaughter
Pre-slaughter supplements - electrolytes

• Reduce weight loss in cattle (Schaefer et al 2001)
  • But not always (Parket et al 2003)

• May reduce incidence of dark cutting (Schaefer et al 1997)
Selection for temperament (fearfulness)

- **Flight Time**
- **Restrain Tests**
- **Isolation box test**
- **Crush Score**
Temperament Tests

Escape and/or avoidance behaviour
Temperament and beef quality

Cattle with poor temperament have:

- Higher incidence of bruising?  
  Inconclusive  

- Higher incidence of dark cutting?  
  No  
  Vosinet et al (1997) – colour only

- Tougher meat?  
  No  
Flight time (FT) and Tenderness

- Genetic gains in FT will result in concurrent gains in tenderness
- FT – $h^2 = 0.3$
- Basis for association is not clear

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Effective handling and management of livestock – Temple Grandin

Curved races
Minimal-slip flooring

Flappers rather than electric goads
Summary

- Pre-slaughter stress can have deleterious effects on beef and lamb quality traits
- Growing evidence for non pHu mediated effects on meat quality due to pre-slaughter stress
  - Need to broaden focus on other traits – those associated with water holding properties
  - Causal mechanisms?
- Strategies to ameliorate losses
  - Effective “low stress” pre-slaughter management
  - Selection for temperament (Bos indicus breeds)??
Thank You