Omega-3 and Sex Ratio of Lambs

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Omega-3 and Omega-6 Fatty Acids

• Fish oil - rich source of omega-3
• Health benefits in humans
  – cardiovascular disease (Simopoulos, 1999)
  – inflammatory diseases (Horrobin, 1999)
  – mental health disorders (Clayton et al., 2007)
• Health benefits in animals?
Omega-3 and Omega-6 in Plants

α-linolenic acid (ALA) - C18:3n-3 - Omega-3

Linoleic acid (LA) - C18:2n-6 - Omega-6
Sources of Omega-3 and Omega-6

**Omega-3**
- Pasture, vegetative cereals (including silage), forage legumes, linseed (flaxseed)
- \( \omega \)-linolenic acid (ALA) (C18:3n-3)
- Eicosapentaenoic acid (EPA) (C20:5n-3)

**Omega-6**
- Grains, soybean oil/meal, safflower, cottonseed meal, sunflower, olive oil
- Linoleic acid (LA) (C18:2n-6)
- Arachidonic acid (AA) (C20:4n-6)
# Omega-3 in Animal Feed

<table>
<thead>
<tr>
<th>Forage</th>
<th>Type</th>
<th>Omega-3 (%)</th>
<th>Omega-6 (%)</th>
<th>n-6:n-3 Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture</td>
<td>Improved</td>
<td>47.9</td>
<td>10.0</td>
<td>0.21</td>
</tr>
<tr>
<td>Pasture</td>
<td>Lucerne</td>
<td>46.6</td>
<td>14.7</td>
<td>0.32</td>
</tr>
<tr>
<td>Cereal</td>
<td>Oat/Pea</td>
<td>44.9</td>
<td>14.8</td>
<td>0.33</td>
</tr>
<tr>
<td>Pasture</td>
<td>Native/Improved</td>
<td>28.8</td>
<td>18.0</td>
<td>0.62</td>
</tr>
<tr>
<td>Silage</td>
<td>Ryegrass</td>
<td>49.1</td>
<td>3.59</td>
<td>0.31</td>
</tr>
<tr>
<td>Silage</td>
<td>Oats</td>
<td>37.1</td>
<td>13.3</td>
<td>0.36</td>
</tr>
<tr>
<td>Silage</td>
<td>Barley</td>
<td>31.4</td>
<td>12.8</td>
<td>0.41</td>
</tr>
<tr>
<td>Grain</td>
<td>Oats</td>
<td>1.1</td>
<td>33.7</td>
<td>31.5</td>
</tr>
<tr>
<td>Grain</td>
<td>Barley</td>
<td>4.3</td>
<td>47.6</td>
<td>11.0</td>
</tr>
<tr>
<td>Grain</td>
<td>Maize</td>
<td>11.0</td>
<td>52.5</td>
<td>4.8</td>
</tr>
<tr>
<td>Cottonseed</td>
<td>CSM</td>
<td>0.3</td>
<td>42.7</td>
<td>164.3</td>
</tr>
</tbody>
</table>

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Metabolism to Prostaglandin

**EPA - Omega-3**

**AA - Omega-6**

- Removal of 2 double bonds

**PGF_{3\alpha}**

**PGF_{2\alpha}**

- Inflammation

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Experimental Work

• Series of studies examining omega-3 and omega-6 fatty acids in sheep
  – Potential inflammation - prostaglandin
  – Sex ratio of lambs
Treatment Diets

**Omega-3**
90% Silage - 10% Molasses

**Omega-6**
70% Oats - 8% CSM

Omega-6 : Omega-3
0.93 : 1

Omega-6 : Omega-3
13.0 : 1

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Study 1 - Prostaglandin Response

• Border Leicester x Merino ewes
  – Silage (n = 15)
  – Oats/CSM (n = 15)

• Oxytocin (10 IU) used to stimulate PG

• Plasma PG metabolite measured prior to oxytocin and for 60 min following oxytocin
Prostaglandin Response

Plasma PGE₂ Metabolite Concentration (Log₁₀ pg/mL)

- Oats/CSM (Omega-6)
- Silage (Omega-3)

Time Following Oxytocin Injection (min)

P = 0.002

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Why Change the Sex Ratio of Lambs?

• Terminal sire enterprises prefer males;
  – faster growth rate
  – increased muscle accumulation

• Self-replacing enterprises and stud breeders prefer females
Omega-3 and Sex Ratio

• Increased proportion of males;
  – North American possum - fish
    (Austad, 1986)
  – Mice - fat supplement
    (Fountain et al., 2008)
  – Sheep polyunsaturated fats??
    (Green et al., 2008)

Sources:
www.poctos.com/live/opossum-american-virginia
www.picturesforcoloring.com/mouse
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Studies 2 to 6 - Sex Ratio

- 5 studies conducted between 2010 and 2012

**X-Breds**
- 2010 - n = 148 per diet
- 2011 - n = 152 per diet
- 2012 - n = 152 (diet crossover)

**Merinos**
- 2011 - n = 160 per diet
- 2012 - n = 160 (diet crossover)

- Diets fed for 6 weeks pre and 17 days post-joining or 6 weeks pre-joining only
### Pen Design - 2010

<table>
<thead>
<tr>
<th>BLOCK/REP 1</th>
<th>BLOCK/REP 2</th>
<th>BLOCK/REP 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pen 1</strong></td>
<td><strong>Pen 2</strong></td>
<td><strong>Pen 3</strong></td>
</tr>
<tr>
<td>Silage (Omega-3)</td>
<td>Oats/CSM (Omega-6)</td>
<td>Silage (Omega-3)</td>
</tr>
<tr>
<td>Pre + Post-conception</td>
<td>Pre + Post-conception</td>
<td>Pre + Post-conception</td>
</tr>
<tr>
<td><strong>Pen 4</strong></td>
<td><strong>Pen 5</strong></td>
<td><strong>Pen 6</strong></td>
</tr>
<tr>
<td>Oats/CSM (Omega-6)</td>
<td>Oats/CSM (Omega-6)</td>
<td>Silage (Omega-3)</td>
</tr>
<tr>
<td>Pre + Post-conception</td>
<td>Pre + Post-conception</td>
<td>Pre + Post-conception</td>
</tr>
</tbody>
</table>

**Silage (Omega-3) - n = 148**

**Oats/CSM (Omega-6) - n = 148**
# Pen Design – 2011-12

<table>
<thead>
<tr>
<th>BLOCK/REP 1</th>
<th>BLOCK/REP 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pen 1</strong></td>
<td><strong>Pen 2</strong></td>
</tr>
<tr>
<td>Oats/CSM (Omega-6)</td>
<td>Silage (Omega-3)</td>
</tr>
<tr>
<td>Pre-conception</td>
<td>Pre + Post-conception</td>
</tr>
</tbody>
</table>

Silage - Pre + Post-conception (Omega-3) - n = 76
Oats/CSM - Pre + Post-conception (Omega-6) - n = 76

Cross-over design in year 2

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Mating and Oestrous Detection

- Natural mating - 2 rams per pen
Blood Omega-3

![Graph showing the variation of Plasma Omega-3 ALA (% Total Fatty Acid) with Day of Feeding Experimental Diets. The graph compares Silage (Omega-3) and Oats/CSM (Omega-6).]

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Omega-3 in Feed and Blood

![Graph showing the relationship between concentration of C18:3n-3 in feed (g/kg DM) and plasma fatty acid concentration (pg/mL). Two data points are shown: Barley Silage and Ryegrass Silage.]
Time to Oestrus

![Graph showing mean time to oestrus for different groups with p-values for significance.]

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Sex Ratio of Lambs

- **X-Breds**
  - Omega-3 Pre-Joining: 44.4%
  - Omega-3 Pre + Post-Joining: 43.4%
  - Omega-6 Pre-Joining: 54.1%
  - Omega-6 Pre + Post-Joining: 57.2%

- **Merinos**
  - Omega-3 Pre-Joining: 49.5%
  - Omega-6 Pre-Joining: 53.1%
  - Omega-3 Pre + Post-Joining: 43.9%
  - Omega-6 Pre + Post-Joining: 64.2%

Significance levels:
- Omega-3 vs Omega-6 Pre-Joining: p = 0.195
- Omega-3 vs Omega-6 Pre + Post-Joining: p = 0.018
- Omega-3 vs Omega-6 Pre-Joining: p = 0.573
- Omega-3 vs Omega-6 Pre + Post-Joining: p = 0.002
Sex Ratio Breed Differences

• Merinos
  – Larger effect when fed pre- and post-joining
• X-Breds
  – Larger effect in singles than twins
• Greatest effect in singles fed pre- and post joining (21% more females)
Omega-3 in Blood and Sex Ratio
Outcomes

- Ewes fed Oats/CSM (high in omega-6) had:
  - more omega-6/less omega-3 in plasma
  - increased PG response to oxytocin
  - shorter time to oestrus
  - approximately 10-15% more female lambs
Where to?

• Overall lamb survival and production
• Lamb metabolism
• Health attributes of meat
• More on-farm studies
On-farm Study

![Graph showing the mean time of joining for two treatment groups, pasture and oats, with a p-value of less than 0.001.]
## Reproduction Outcomes

<table>
<thead>
<tr>
<th>Reproduction Measure</th>
<th>Omega-3 (Pasture)</th>
<th>Omega-6 (Oats)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of ewes pregnant (%)</td>
<td>89.4</td>
<td>87.5</td>
<td>0.479</td>
</tr>
<tr>
<td>Mean foetal number</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For ewes pregnant</td>
<td>1.06 (± 0.02)</td>
<td><strong>1.22</strong> (± 0.03)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>For all ewes</td>
<td>0.95 (± 0.02)</td>
<td><strong>1.06</strong> (± 0.03)</td>
<td>0.009</td>
</tr>
</tbody>
</table>
Practicalities – What do we think works?

Feed Oats at 500 g/hd/day
Feed daily to start then every second or third day

-4 -3 -2 -1 0 1 2 3 4 5 6
Week of Joining

Start feeding ewes oats
Feed some oats to rams
Put rams out with ewes
End of joining
In Summary

Omega-3
Silage
More Males

Omega-6
Oats/Cottonseed Meal
More Females

Grain for Girls?
Acknowledgements

- WWAI: Greg Clark, Steven Huckell, Michael Loiterton, Rex Edis, John Moore, Craig Lihou, Patricia O’ Keeffe
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