Associations of feed efficiency with reproductive development and semen quality in young bulls

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Outline

- Introduction
- Hypothesis
- Objectives
- Material & Methods
- Results
- Discussion & Results
- Future Directions
- Acknowledgements
Introduction
Introduction

- **Feed Efficiency**

- **Semen quality**
  - (Awda et al., 2012; Fontoura et al., 2015)

- **Scrotal circumference**
  - (Awda et al., 2012)

- **Testes echogenicity**
  - (Fontoura et al., 2015)

- **Testes microscopy**
  - (Fontoura et al., 2015)

- **Scrotal temperature**
  - (Fontoura et al., 2015)
Introduction

**Efficient**

**Inefficient**

**Metabolic differences**

- Metabolic hormones (Kelly et al., 2010)
- Liver metabolism (Lancaster et al., 2014)
- Mitochondrial respiration (Kolath et al., 2006)

**Blood metabolite profile** (Gonano et al., 2014)

**Impact on sexual maturity and fertility related measures** (Dunn and Moss, 1992)
Hypothesis

- Evidence suggest that both feed efficiency and fertility vary with age, body composition and physiological stage. Thus, young bulls with divergent feed efficiency may display corresponding phenotypic variation in the reproductive system and intermediary metabolism.
Objectives

Sexual maturity and fertility related measures
Material & Methods: Populations

- Three populations
  - Population 1 → 16 bulls
  - Population 2 → 49 bulls
  - Population 3 → 109 bulls

- Two research stations
  - Eastern Canada (★)
  - Central Canada (★)

- Pie chart showing the proportion of different breeds among the populations:
  - Angus 26%
  - Simmental 31%
  - Charolais 13%
  - Red Angus 7%
  - Others 23%
Material & Methods: Timeline

- Testes ultrasound
- Scrotum infrared thermography
- Complete blood count
- Semen collection

D 0
D 56
D 112
Slaughter

- Testes ultrasound
- Body ultrasound
- Body weight
- Weight
- Histology
Material & Methods: Performance Evaluation

- 112 days daily feed intake

### Chemical Composition (As Fed) Eastern Canada

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter (%)</td>
<td>40.41</td>
</tr>
<tr>
<td>Crude Protein %; (N x 6.25)</td>
<td>6.05</td>
</tr>
<tr>
<td>Starch (%)</td>
<td>8.55</td>
</tr>
<tr>
<td>Neutral Detergent Fiber (%)</td>
<td>16.16</td>
</tr>
<tr>
<td>Acid Detergent Fiber (%)</td>
<td>10.09</td>
</tr>
<tr>
<td>Total Digestible Nutrients (%)</td>
<td>29.55</td>
</tr>
</tbody>
</table>

### Chemical Composition (As Fed) Central Canada

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter (%)</td>
<td>54.00</td>
</tr>
<tr>
<td>Crude Protein %</td>
<td>7.55</td>
</tr>
<tr>
<td>Starch (%)</td>
<td>24.19</td>
</tr>
<tr>
<td>Neutral Detergent Fiber (%)</td>
<td>9.86</td>
</tr>
<tr>
<td>Acid Detergent Fiber (%)</td>
<td>5.57</td>
</tr>
<tr>
<td>Total Digestible Nutrients (%)</td>
<td>46.70</td>
</tr>
</tbody>
</table>
Material & Methods: Performance Evaluation
Material & Methods: Feed Efficiency Determination

- Residual Feed Intake (RFI)

**Predicted Feed Intake (kg/day)** = Intercept + \( \beta_1 \) (ABW) + \( \beta_2 \) (ADG) + \( \beta_3 \) (Back Fat) + \( \beta_4 \) (Rump Fat) + \( \beta_5 \) (Marbling) + \( \beta_6 \) (Ribeye Area) + RFI

RFI (kg/day) = Feed Intake – Predicted Feed Intake

**Population 1:** \( R^2 = 0.60 
Population 2:** \( R^2 = 0.67 
Population 3:** \( R^2 = 0.59 

Fatness
Leaness
Material & Methods: Blood Parameters

- Complete blood count (CBC)
  - White Blood Cells
    - Neutrophils
    - Lymphocyte
    - Monocyte
    - Eosinophil
    - Basophil
  - Red Blood Cells
    - Hemoglobin
    - Hematocrit
    - Mean Cell Volume
  - Proteins
    - Total Solutes Protein
  - Platelets
Material & Methods: Scrotum Infrared Thermography

- **Image Collection**
  - ThermaCam SC2000®
- **Image Analysis**
  - ThermaCam Researcher 2001® software

Scrotal Surface Temperature

Scrotal Surface Temperature Base (T) and Apex (B)
Material & Methods: Scrotal Circumference
Material & Methods: Testes Ultrasound

- **Image collection**
  - Aloka SSD-500® with 5 MHz linear array probe

- **Image analysis**
  - Pixel intensity using ImageJ®

![Image collection with Aloka SSD-500®](image)

![Ultrasound image with arrow indicating Mediastinum](ultrasound)

![ImageJ analysis](image)
Material & Methods: Semen Quality

- **Semen collection**
  - Pulsator IV electro ejaculator®
- **Sperm motility (%)**
Material & Methods: Semen Quality

❖ Sperm morphology (%) and viability (%)

- Sperm morphology (%)
  - Head Defect
  - Mid-Piece Defect
  - Loose Head
  - Proximal Droplet
  - Tail Defect

- Viability (%)
  - Alive
  - Dead
Testes morphology and histology

Material & Methods: Testes Assessment

Classifications of tubules

- Immature
- Mature
- Reaching Maturity

40x

Classification of tubules

- Tubule area
- Lumen area

(2009)
Material & Methods: Statistical Analysis

- Complete blood count, semen quality, scrotal circumference, testes weight and testes histology

General Linear Model
- PROC GLM SAS®

\[ Y_{ijkl} = \mu + R_i + B_j + G_k + \beta(A_l) + \varepsilon_{ijkl} \]

Example:
Motility % = \mu + Feed Efficiency Class + Breed + Population + Age + Error

Bottom 25%
Efficient: -1.89 ± 0.67 kg/day
Inefficient: 1.95 ± 0.79 kg/day

Top 25%
Material & Methods: Statistical Analysis

Scrotum infrared thermography and testes ultrasound

General Linear Model

\[ Y_{ijklmn} = \mu + R_i + B_j + G_k + \beta(A_{ijkl}) + \delta(T_{ijkm}) + \tau(H_{ijkn}) + \varepsilon_{ijklmn} \]

Example:
Average temperature = \( \mu + \) Feed Efficiency Class + Breed + Population + Age + Temperature + Humidity + Error

EFFICIENT: -1.89 ± 0.67 kg/day
INEFFICIENT: 1.95 ± 0.79 kg/day
Material & Methods: Statistical Analysis

Repeated testes ultrasound

**Mixed Model**

- PROC Mixed SAS®

\[ Y_{ijklmno} = \mu + R_i + B_j + G_k + \beta(A_{ijkl}) + \delta(T_{ijkm}) + \tau(H_{ijkn}) + \eta(D_{ijko}) + \epsilon_{ijklmno} \]

Example:

Mean pixel intensity = \( \mu + \) Feed Efficiency Group + Breed Group + Population Group + Age + Temperature + Humidity + Date + Error

Bottom 25%  Top 25%

EFFICIENT: -1.89 ± 0.67 kg/day
INEFFICIENT: 1.95 ± 0.79 kg/day
## Results & Discussion: Performance Evaluation

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Efficient</th>
<th>Inefficient</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (days)</td>
<td>403</td>
<td>397</td>
<td>N.S.</td>
</tr>
<tr>
<td>Final Body Weight (kg)</td>
<td>480</td>
<td>486</td>
<td>N.S.</td>
</tr>
<tr>
<td>Average Feed Intake (kg/day)</td>
<td>16.81</td>
<td>20.52</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Average Daily Gain (kg/day)</td>
<td>1.81</td>
<td>1.88</td>
<td>N.S.</td>
</tr>
<tr>
<td>Final Back Fat (mm)</td>
<td>4.11</td>
<td>4.18</td>
<td>N.S.</td>
</tr>
<tr>
<td>Final Ribeye Area (cm²)</td>
<td>76.05</td>
<td>78.40</td>
<td>N.S.</td>
</tr>
<tr>
<td>Final Rump Fat (mm)</td>
<td>3.92</td>
<td>3.87</td>
<td>N.S.</td>
</tr>
<tr>
<td>Final Marbling (Score: 1-10)</td>
<td>6.45</td>
<td>6.32</td>
<td>N.S.</td>
</tr>
<tr>
<td>Residual Feed Intake (kg/day)</td>
<td>-1.99</td>
<td>1.78</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>
## Results & Discussion: Complete Blood Count

<table>
<thead>
<tr>
<th>CBC parameters</th>
<th>Efficient</th>
<th>Inefficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Blood Cells (x10⁹/L)</td>
<td>9.42</td>
<td>8.50</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Neutrophils (x10⁹/L)</td>
<td>3.27</td>
<td>4.04</td>
<td>N.S.</td>
</tr>
<tr>
<td>Lymphocytes (x10⁹/L)</td>
<td>4.70</td>
<td>4.23</td>
<td>N.S.</td>
</tr>
<tr>
<td>Monocytes (x10⁹/L)</td>
<td>0.54</td>
<td>0.30</td>
<td>&lt;0.10</td>
</tr>
<tr>
<td>Eosinophils (x10⁹/L)</td>
<td>0.33</td>
<td>0.11</td>
<td>&lt;0.10</td>
</tr>
<tr>
<td>Basophils (x10⁹/L)</td>
<td>0.11</td>
<td>0.13</td>
<td>N.S.</td>
</tr>
<tr>
<td>Red Blood Cells (x10¹²/L)</td>
<td>8.50</td>
<td>8.37</td>
<td>N.S.</td>
</tr>
<tr>
<td>Hemoglobin (g/L)</td>
<td>129.81</td>
<td>128.36</td>
<td>N.S.</td>
</tr>
<tr>
<td>Hematocrit (L/L)</td>
<td>0.35</td>
<td>0.35</td>
<td>N.S.</td>
</tr>
<tr>
<td>Mean Cell Volume (fL)</td>
<td>40.88</td>
<td>41.35</td>
<td>N.S.</td>
</tr>
<tr>
<td>Platelets (x10⁹/L)</td>
<td>352.21</td>
<td>331.39</td>
<td>N.S.</td>
</tr>
<tr>
<td>Total Solute Protein (g/L)</td>
<td>74.24</td>
<td>72.03</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

Higher white blood cells in efficient steers (Richardson et al., 2002)

Lower neutrophils and higher lymphocytes in efficient heifers (Crane et al., 2015)
## Results & Discussion: Scrotum Infrared Thermography

### Scrotal Surface Temperature

**Base (T) and Apex (B)**

![Infrared Image](image)

### Average Scrotum Temperature

<table>
<thead>
<tr>
<th>Infrared Parameter</th>
<th>Efficient</th>
<th>Inefficient</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Average Temperature</td>
<td>31.76</td>
<td>32.87</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Base Maximum Temperature</td>
<td>33.49</td>
<td>34.16</td>
<td>N.S.</td>
</tr>
<tr>
<td>Base Minimum Temperature</td>
<td>28.91</td>
<td>30.50</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Base Standard Deviation</td>
<td>0.99</td>
<td>0.72</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Apex Average Temperature</td>
<td>24.67</td>
<td>25.14</td>
<td>N.S.</td>
</tr>
<tr>
<td>Apex Maximum Temperature</td>
<td>26.49</td>
<td>27.26</td>
<td>N.S.</td>
</tr>
<tr>
<td>Apex Minimum Temperature</td>
<td>21.64</td>
<td>22.09</td>
<td>N.S.</td>
</tr>
<tr>
<td>Apex Standard Deviation</td>
<td>0.99</td>
<td>1.20</td>
<td>N.S.</td>
</tr>
<tr>
<td>Base – Apex Average Temperature</td>
<td>7.10</td>
<td>7.73</td>
<td>N.S.</td>
</tr>
<tr>
<td>Average Scrotum Temperature</td>
<td>28.48</td>
<td>29.54</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

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**Difference in temperature variation at base of the scrotum**  
(Fontoura et al., 2015)

**Efficient bulls have decreased testicular heat dissipation**
Results & Discussion: Scrotal Circumference & Testes Weight

No difference in scrotal circumference between efficiency groups
(Hafla et al., 2012; Wang et al., 2012; Fontoura et al., 2015)

Higher scrotal circumference between efficiency groups
(Awda et al., 2012)
Results & Discussion: Testes Ultrasound

Lower pixel intensity in efficient bulls at semen collection (Fontoura et al., 2015)

Efficient bulls take longer to have mature testicular tissue
## Results & Discussion: Semen Quality

<table>
<thead>
<tr>
<th>Semen Quality Parameters (%)</th>
<th>Efficient</th>
<th>Inefficient</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sperm Motility</td>
<td>75.30</td>
<td>71.41</td>
<td>N.S.</td>
</tr>
<tr>
<td>Normal Sperms</td>
<td>74.85</td>
<td>71.30</td>
<td>N.S.</td>
</tr>
<tr>
<td>Head Abnormalities</td>
<td>11.34</td>
<td>10.92</td>
<td>N.S.</td>
</tr>
<tr>
<td>Mid-piece Abnormalities</td>
<td>8.67</td>
<td>10.20</td>
<td>N.S.</td>
</tr>
<tr>
<td>Tail Abnormalities</td>
<td>2.16</td>
<td>3.16</td>
<td>N.S.</td>
</tr>
<tr>
<td>Proximal Droplets</td>
<td>1.97</td>
<td>2.53</td>
<td>N.S.</td>
</tr>
<tr>
<td>Loose Heads</td>
<td>4.01</td>
<td>4.01</td>
<td>N.S.</td>
</tr>
<tr>
<td>Dead Sperms</td>
<td>28.07</td>
<td>29.47</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

**Lower sperm motility**  
(Wang et al., 2012; Awda et al., 2012; Fontoura et al., 2015)  
**No difference between efficiency class**  
(Hafa et al., 2012)

**Higher sperm abnormalities**  
(Hafla et al., 2012; Fontoura et al., 2015)  
**No difference between efficiency class**  
(Wang et al., 2012; Awda et al., 2012)
Results & Discussion: Testes Histology

<table>
<thead>
<tr>
<th>Seminiferous Tubules Parameters</th>
<th>Efficient</th>
<th>Inefficient</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubule Area (mm²)</td>
<td>189.23</td>
<td>182.21</td>
<td>N.S.</td>
</tr>
<tr>
<td>Lumen Area (mm²)</td>
<td>70.28</td>
<td>71.57</td>
<td>N.S.</td>
</tr>
<tr>
<td>Mature (%)</td>
<td>96.56</td>
<td>95.66</td>
<td>N.S.</td>
</tr>
<tr>
<td>Reaching Maturity (%)</td>
<td>2.04</td>
<td>2.33</td>
<td>N.S.</td>
</tr>
<tr>
<td>Immature (%)</td>
<td>0.04</td>
<td>0.31</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

- Larger tubule diameter in efficient bulls
- No difference in classification between efficiency groups

(Fontoura et al., 2015)
Efficient bulls = less developed testes $\rightarrow$ lower scrotal temperature
Conclusion
Future Directions

- **Sexual organs histology**
  - Seminal Vesicles
  - Epididymis
  - Vascular Cone

- **Metabolic and sexual hormones**
  - Inefficient
  - Efficient
  - $T_3$ (nmol/L)
  - Days prior to slaughter
  - D33, D32, D28, D15, D11, D7, D5
  - 2.76a, 2.56b
Acknowledgment

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  - Dr. Flavio Schenkel
  - Dr. Robert Foster

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  - Ananda Fontoura
  - Stephanie Lam
  - Alaina Macdonald
  - Jasper Munro

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  - Kenny Thompson
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Circadian metabolomic profile of beef heifers and associations with feed efficiency

Alaina Macdonald¹, Ian Burton⁴, Tobias Karakach⁴, Stephanie Lam¹, Ananda Fontoura¹, Stéphanie Bourgon², Stephen Miller³, Yuri Montanholi²

Session 27: New sources of phenotypes in cattle production – Part 1
9:30AM