Microstructure and function of the thyroid gland may relate to feed efficiency in the bovine

J. Ormon\textsuperscript{1}, S. Bourgon\textsuperscript{1}, J. Munro\textsuperscript{1}, A. Macdonald\textsuperscript{2}, S. Lam\textsuperscript{2}, S. Miller\textsuperscript{2,3}, Y. Montanholi\textsuperscript{1}

\textsuperscript{1}DALHOUSSIE UNIVERSITY
\textsuperscript{2}UNIVERSITY OF GUELPH
\textsuperscript{3}agresearch
BIOLOGICAL BASIS OF FEED EFFICIENCY
Outline

- Thyroid hormones: simple examples
  - Oestrous detection
  - Liver abscess detection
  - Feed efficiency & spot sampling

- Thyroid hormones: complex examples
  - Circadian patterns (T3 & T4)
  - Other organs and tissue structure

44 ± 12 g
"Simple examples"

- Thyroid hormones: simple examples
  - Oestrous detection
  - Liver abscess detection
  - Feed efficiency & spot sampling

1 + 1 = 2
Oestrous detection

- T3: Major indicator of oestrous

- Logistic regression
- 92% of certainty

Crane et al (2016), Reproduction in Domestic Animals, in press
Biological characterization of the estrous cycle in lactating Holstein cows

Y. Montanholi\textsuperscript{1}, S. Bourgon\textsuperscript{1}, A. Macdonald\textsuperscript{2}, P. Park\textsuperscript{2}, S. Lam\textsuperscript{2}, M. Kozak\textsuperscript{2}, B. Potvin\textsuperscript{2}, K. Colliver\textsuperscript{2}, L. Haas\textsuperscript{2}, A. Rocha\textsuperscript{2}, S. Miller\textsuperscript{2,3}
Liver abscess detection

- **T4: indicator of liver abscess**

- 20% reduction in abscessed samples

- **Poor performance: Reduced FG & ADG**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Abscessed</th>
<th>Normal</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3 (nmol/L)</td>
<td>2.77</td>
<td>2.80</td>
<td>0.84</td>
</tr>
<tr>
<td>T4 (nmol/L)</td>
<td>89.43</td>
<td>102.0</td>
<td>0.01</td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>5.14</td>
<td>6.09</td>
<td>0.03</td>
</tr>
<tr>
<td>Cholesterol (mmol/L)</td>
<td>2.43</td>
<td>3.04</td>
<td>0.01</td>
</tr>
<tr>
<td>Albumin (g/L)</td>
<td>32.11</td>
<td>36.35</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Macdonald et al (2016), Veterinary Record Open, in press
Feed efficiency & spot sampling

- Feed efficiency determination: residual feed intake (RFI)

Koch et al 1963:

**EFFICIENCY OF FEED USE IN BEEF CATTLE**

Robert M. Koch, L. A. Swiger, Doyle Chambers and K. E. Gregory

University of Nebraska, Oklahoma State University and United States Department of Agriculture

Feed intake = BW + BW_{variation}
Feed efficiency & spot sampling

- RFI determination: growing cattle

Feed intake = BW + Bw\text{variation} + Backfat + Marbling + Rump\_fat + Ribeye

Montanholi et al. (2009), Livestock Science, 125:22-30.
Feed efficiency & spot sampling

- RFI determination: growing and pregnant cattle

\[ \text{Feed intake} = \text{BW} + B_{\text{w variation}} + \text{Backfat} + \text{Marbling} + \text{Rump_fat} + \text{Ribeye} + \text{Age} + \text{Gestation} \]


Feed efficiency & spot sampling

- RFI and T3: grass-fed replacement heifers

<table>
<thead>
<tr>
<th>Traits</th>
<th>Efficient</th>
<th>Inefficient</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFI (kg/d)</td>
<td>-0.83</td>
<td>+0.85</td>
<td>0.01</td>
</tr>
<tr>
<td>Feed to Gain</td>
<td>7.92</td>
<td>9.70</td>
<td>0.01</td>
</tr>
<tr>
<td>ADG (kg/d)</td>
<td>0.71</td>
<td>0.74</td>
<td>0.35</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>339</td>
<td>349</td>
<td>0.25</td>
</tr>
<tr>
<td>Rib-eye (cm²)</td>
<td>48</td>
<td>49</td>
<td>0.16</td>
</tr>
<tr>
<td>Backfat (mm)</td>
<td>2.31</td>
<td>2.35</td>
<td>0.82</td>
</tr>
</tbody>
</table>


120 d on test, every 28 d
Feed efficiency & spot sampling

- RFI and T3: grass-fed replacement heifers

<table>
<thead>
<tr>
<th>Traits</th>
<th>Value 1</th>
<th>Value 2</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3 (nmol/L)</td>
<td>1.81</td>
<td>1.90</td>
<td>0.06</td>
</tr>
<tr>
<td>Mean cell hemoglobin (pg)</td>
<td>16.0</td>
<td>16.4</td>
<td>0.01</td>
</tr>
<tr>
<td>Red blood cell count (10^6 cells/μL)</td>
<td>7.65</td>
<td>7.67</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Feed efficiency & spot sampling

- RFI and T3: grain-fed young bulls on-farm

- No difference: T4

Feed efficiency & spot sampling

- Transportation and non-routine handling effects

<table>
<thead>
<tr>
<th>Analyte</th>
<th>On-farm</th>
<th>Slaughter</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creatine kinase (U/L)</td>
<td>100</td>
<td>304</td>
<td>0.01</td>
</tr>
<tr>
<td>Cortisol (ng/mL)</td>
<td>24.3</td>
<td>49.3</td>
<td>0.03</td>
</tr>
<tr>
<td>IGF-1 (ng/mL)</td>
<td>485</td>
<td>396</td>
<td>0.02</td>
</tr>
<tr>
<td>Osmolality (mmol/L)</td>
<td>285</td>
<td>296</td>
<td>0.01</td>
</tr>
<tr>
<td>T3 (nmol/L)</td>
<td>2.66</td>
<td>2.78</td>
<td>0.98</td>
</tr>
<tr>
<td>T4 (nmol/L)</td>
<td>84.6</td>
<td>97.8</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Complex examples

- **Thyroid hormones: complex examples**
  - Circadian patterns (T3 & T4)
  - Other organs and tissue structure
Circadian patterns

- T3 and T4: physiological state and feed efficiency

puberty → early pregnancy → late pregnancy
Circadian patterns

- T3 by physiological state

![Graph showing T3 levels by physiological state](image)
Circadian patterns

- T4 by physiological state

![Graph showing T4 levels over time for different physiological states.](image)
Circadian patterns

- Feed efficiency & T3 by physiological state

![Graph showing T3 levels over the day with pubertal stages labeled as 'a' and 'b'.]
Circadian patterns

- Feed efficiency & T3 by physiological state

**Graphs:**
- Time of the day (8:00 to 5:00)
- T3 (nmol/L) range from 1.0 to 2.2
- Comparison between early pregnancy and late pregnancy
- markers a and b indicate different time points or conditions
Circadian patterns

- Feed efficiency & T4 by physiological state

![Graph showing T4 levels over time, with peak around 20:00 and dip at 5:00.]

PUBERTY
Circadian patterns

- Feed efficiency & T4 by physiological state

![Graph showing T4 levels over time for early and late pregnancy.](Image)
Circadian patterns

- T3 & T4: oxygen consumption

LATE PREGNANCY
Circadian patterns

- T3: oxygen consumption
Circadian patterns

- T3 and oxygen consumption

![Graph showing circadian patterns of oxygen consumption and T3 levels in late pregnancy.](image-url)
Relationships with liver $O_2$
Relationships with liver $O_2$
Relationships with liver $O_2$

- T3 and oxygen consumption

LATE PREGNANCY

$O_2$

2.54 $\mu$mol/min/g DM

1.57 $\mu$mol/min/g DM

T3

T4

0.46

0.44
Relationships with radiant heat

- Infrared thermography
Relationships with radiant heat

- T4 and thermographs

\[ T4 - 0.36 \]
\[ T4 - 0.29 \]
Other organs & tissue structure

TSH

T4  T3

T4

T3

Heart

Cow

Other organs

Tissue structure
Other organs & tissue structure

- Heart physiology & structure research

Best Oral Presentation
awarded to

Jasper Munro

at the 66th Annual Meeting of the European Association for Animal Production in Warsaw, Poland,
August 31st - 4 September 2015

Philippe Chemineau
President of the EAAP
Other organs & tissue structure

- The feed inefficient cattle heart

**Structure:**
- Lower R-ventricle weight
- Thinner R-ventricle wall
- Larger myocyte width

**Function:**
- Increased resting heart rate
- Diminished stroke volume
- Larger blood volume

Other organs & tissue structure

- Thyroid hormones & heart structure and function

T3

TSH

Myocyte width

Sarcomere length

0.66

0.65

0.42

-0.62

-0.38

Blood volume

Time after administration (min)

Blood volume

1000x
Other organs & tissue structure

- Thyroid hormones and heart rate overnight

**Munro et al (2016), Animal, 1:1-9.**
Other organs & tissue structure

- Thyroid hormones & HR during transport and slaughter

- TSH: -0.72 ns
- T3: ns ns
- T4: ns 0.89 ns
Other organs & tissue structure

- Thyroid hormones & blood cells

![Diagram showing thyroid hormones and blood cells with values:

- T3: 0.42
- T4: 0.40
- TSH: 0.27
- TSH: -0.31

Red cells and white cells with T3 and T4 connections.]

- T3: 0.42
- T4: 0.40
- TSH: 0.27
- TSH: -0.31
Other organs & tissue structure
Other organs & tissue structure

Other organs & tissue structure

- Thyroid hormones & sexual development

Higher pixel intensity

Other organs & tissue structure

- Thyroid hormones & sexual development

Bourgon et al (2016),AAAA.
Other organs & tissue structure

- Thyroid hormones & semen quality

JOURNAL OF DAIRY SCIENCE, 1961, 44:1537-1543

REPRODUCTIVE CAPACITY OF DAIRY BULLS. I. TECHNIQUE FOR DIRECT MEASUREMENT OF GONADAL AND EXTRA-GONADAL SPERM RESERVES

R. P. AMANN AND J. O. ALMQUIST
Dairy Breeding Research Center, Department of Dairy Science
The Pennsylvania State University, University Park

Spermatogenesis

\[ \sum T_3 + T_4 = 0.28 + 0.42 = 0.7 \]

70 days
Other organs & tissue structure
Other organs & tissue structure

- Pituitary gland histomorphometry

Anterior pituitary

Posterior pituitary

Mucoid wedge

Pars intermedia
Other organs & tissue structure

- Pituitary gland histomorphometry

Pituitary gland histomorphometry

- **Anterior pituitary**
  - 68%
  - P = 0.04

- **Posterior pituitary**
  - 17%
  - P = 0.02

Acidophils Basophils Immunostaining

62% 12%
Other organs & tissue structure

- **Thyroid gland histomorphometry**

- **Cell metrics:**
  - Cell area & perimeter
  - Nuclei area & perimeter
  - Cell height

- **Follicle average size**
Other organs & tissue structure

- Thyroid gland histomorphometry

- TSH (0.57)
  - Nuclei area (NS)
  - Follicle size (NS)

- T4 (0.36)
  - Cell area (0.55)
  - Nuclei area (NS)

- T3
  - Cell/nuclei (0.57)

Images:
- 1000x: Nuclei area
- 1000x: Cell area
- 40x: Follicle size
Other organs & tissue structure

- Thyroid histomorphometry and hormones by RFI groups

<table>
<thead>
<tr>
<th>Traits</th>
<th>Group 1</th>
<th>Group 2</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3 (nmol/L)</td>
<td>2.87</td>
<td>3.19</td>
<td>0.04</td>
</tr>
<tr>
<td>T4 (nmol/L)</td>
<td>95.0</td>
<td>115</td>
<td>0.01</td>
</tr>
<tr>
<td>TSH (ng/mL)</td>
<td>5.74</td>
<td>3.75</td>
<td>0.08</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traits</th>
<th>Group 1</th>
<th>Group 2</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follicle size (μm²)</td>
<td>4440</td>
<td>4211</td>
<td>0.04</td>
</tr>
<tr>
<td>Cell size (μm²)</td>
<td>69.5</td>
<td>65.5</td>
<td>0.09</td>
</tr>
<tr>
<td>Nuclei size (μm²)</td>
<td>21.1</td>
<td>19.6</td>
<td>0.01</td>
</tr>
<tr>
<td>Cell : nuclei ratio</td>
<td>3.29</td>
<td>3.35</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Other organs & tissue structure

- More on histomorphometry and feed efficiency...

<table>
<thead>
<tr>
<th></th>
<th>Duodenum</th>
<th>Ileum</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of cells</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duodenum</td>
<td>30.3</td>
<td>33.2</td>
<td>0.04</td>
</tr>
<tr>
<td>Ileum</td>
<td>33.6</td>
<td>37.2</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Size of the cells</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duodenum</td>
<td>94.6</td>
<td>94.7</td>
<td>0.98</td>
</tr>
<tr>
<td>Ileum</td>
<td>83.5</td>
<td>83.7</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Influence of feed efficiency and physiological state on rumen VFA and microbial profiles in cattle

S Lam¹, J Munro², J Cant¹, L Guan³, M Steele³, F Schenkel¹, S Miller¹,⁴, Y Montanholi²
Remarks

- Productive performance
- Reproduction
- Welfare
- Health

➢ Support to other disciplines

"REFINED" PHENOTYPES

Multi-stream & Multidisciplinary Technologies

PHYSIOLOGY

HUSBANDRY