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

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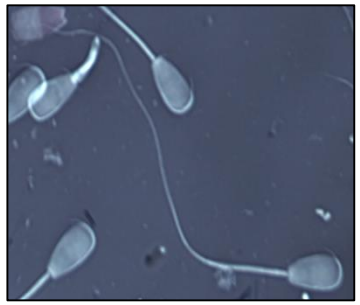
Outline

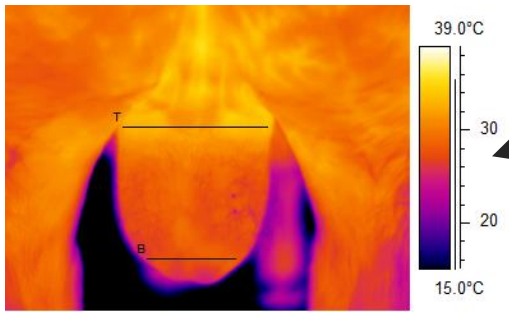
- Introduction
- Hypothesis
- Objectives
- Material & Methods
- Results
- Discussion & Results
- Future Directions
- Acknowledgements

Introduction

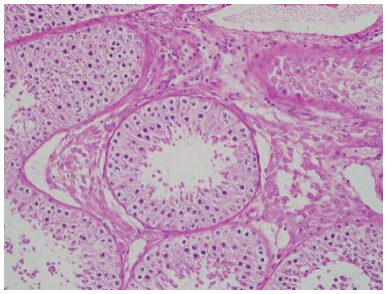


Introduction

↑ Feed Efficiency

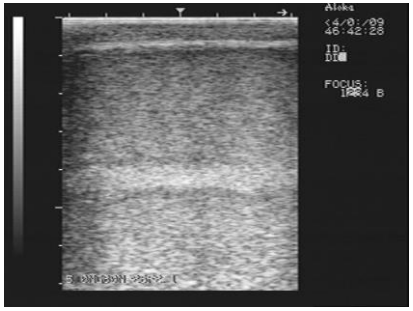


❖ **Scrotal temperature**
(Fontoura et al., 2015)



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

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



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

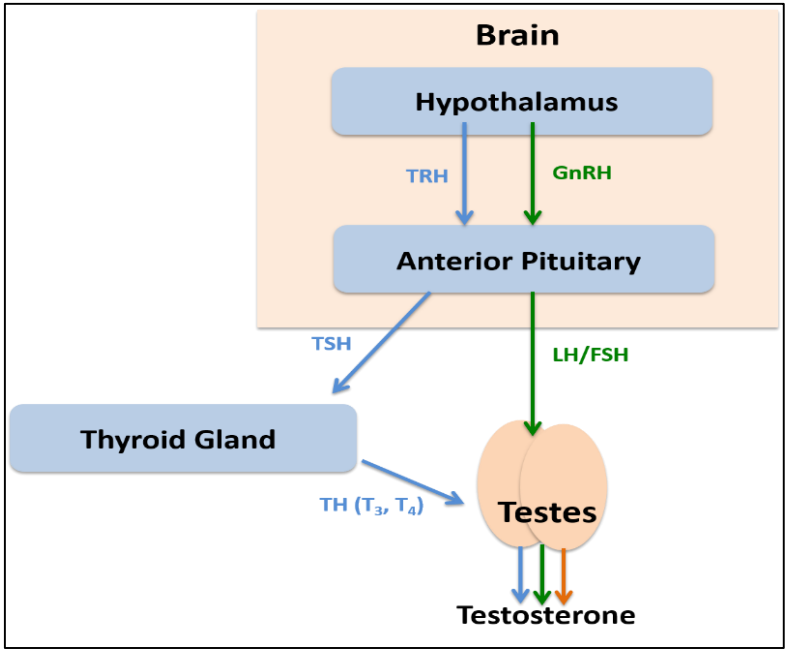
❖ **Semen quality**
(Awda et al 2012; Fontoura et al 2015)

Introduction

Efficient

Inefficient

VS.



Metabolic differences

Metabolic hormones
(Kelly et al., 2010)

Blood metabolite profile
(Gonano et al., 2014)

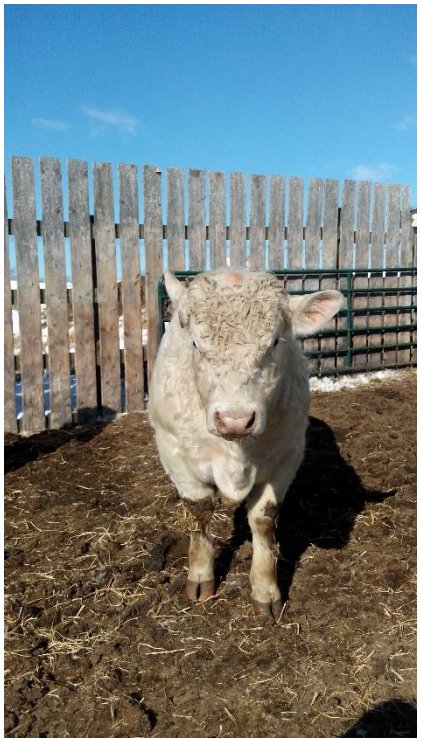
Liver metabolism
(Lancaster et al., 2014)

Mitochondrial respiration
(Kolath et al., 2006)

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

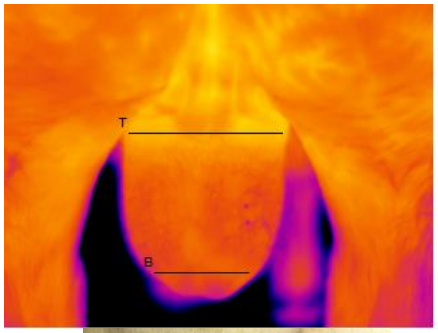
Hypothesis

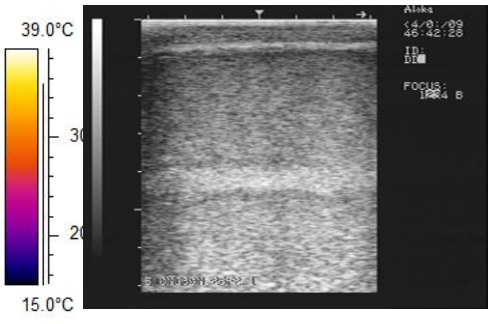
- Evidence suggest that both feed efficiency and fertility vary with age, body composition and physiological stage. Thus, young bulls with divergent feed efficiency may display corresponding phenotypic variation in the reproductive system and intermediary metabolism.

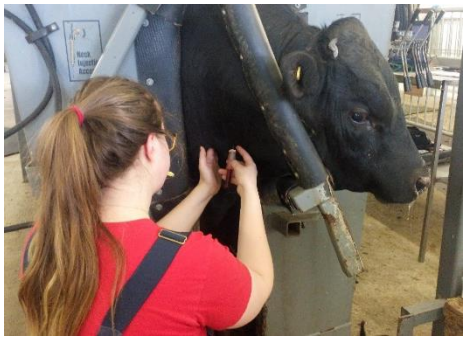


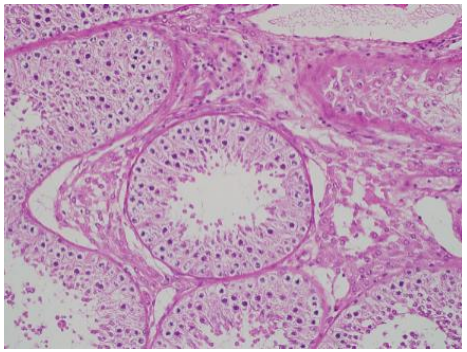
Objectives

Sexual maturity
and fertility
related measures



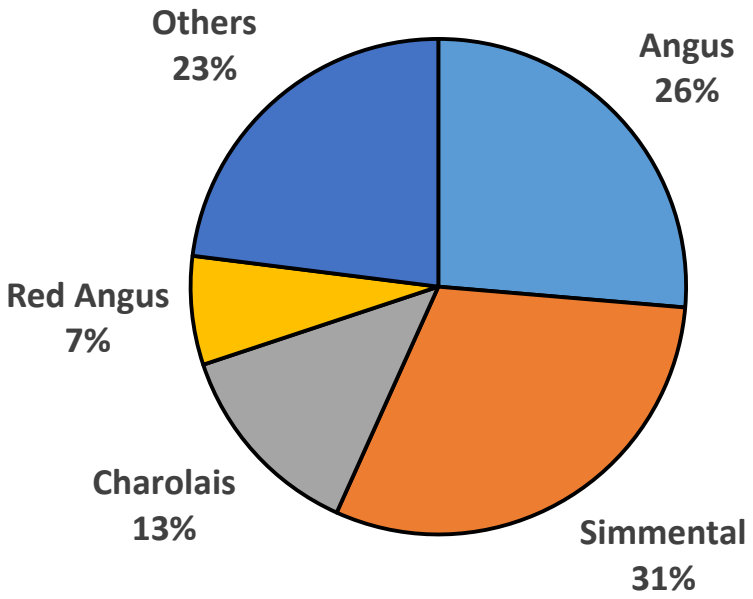






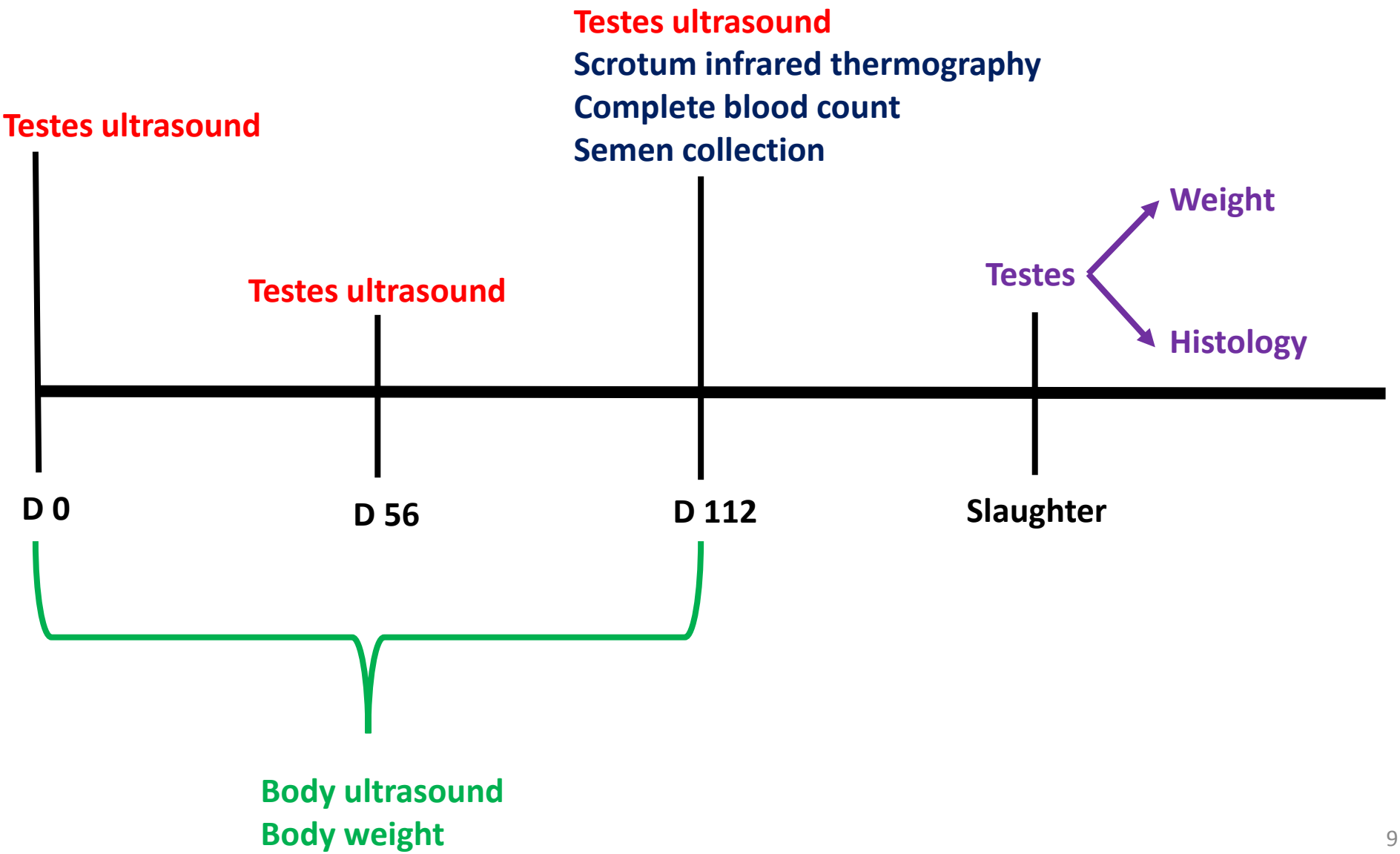
Material & Methods: Populations

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



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

Material & Methods: Timeline



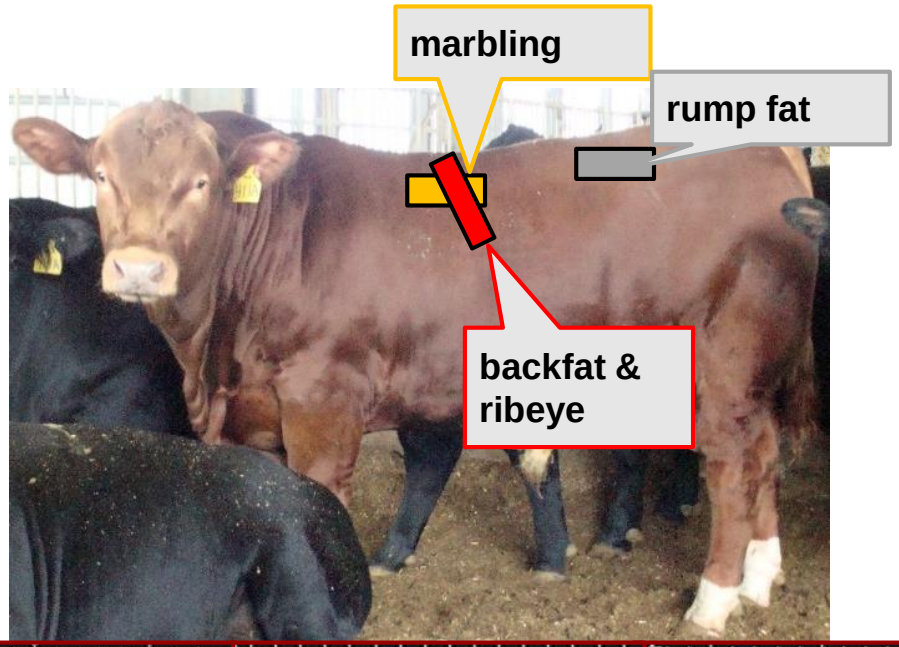
Material & Methods: Performance Evaluation

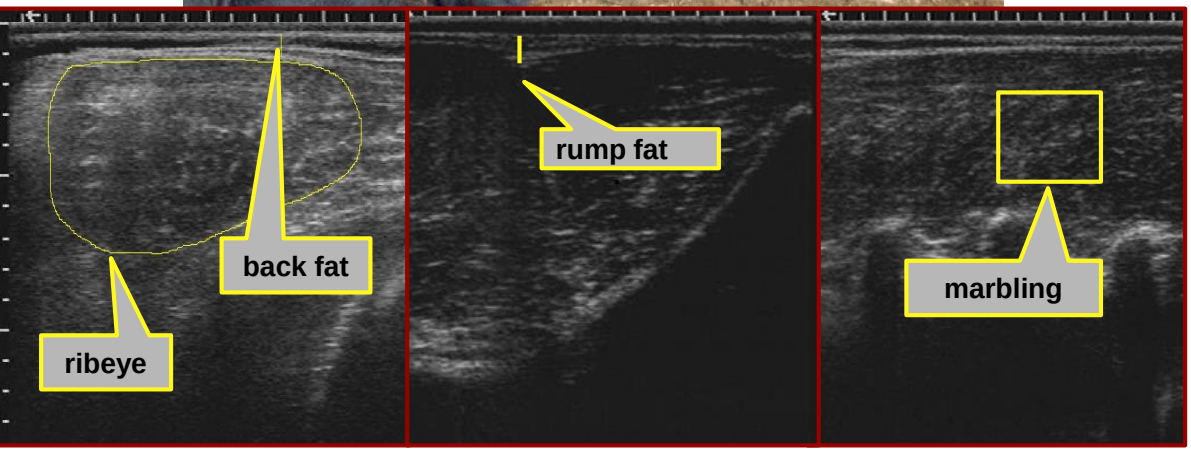
- 112 days daily feed intake

Chemical Composition (As Fed) Eastern Canada	
Dry Matter (%)	40.41
Crude Protein %; (N x 6.25)	6.05
Starch (%)	8.55
Neutral Detergent Fiber (%)	16.16
Acid Detergent Fiber (%)	10.09
Total Digestible Nutrients (%)	29.55

Chemical Composition (As Fed) Central Canada	
Dry Matter (%)	54.00
Crude Protein %	7.55
Starch (%)	24.19
Neutral Detergent Fiber (%)	9.86
Acid Detergent Fiber (%)	5.57
Total Digestible Nutrients (%)	46.70

Material & Methods: Performance Evaluation





Material & Methods: Feed Efficiency Determination

- Residual Feed Intake (RFI)

Predictided Feed Intake (kg/day) = Intercept + β_1(ABW) + β_2(ADG) + β_3(Back Fat) + β_4(Rump Fat) + β_5(Marbling) + β_6(Ribeye Area) + RFI

Fatness

Leaness

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

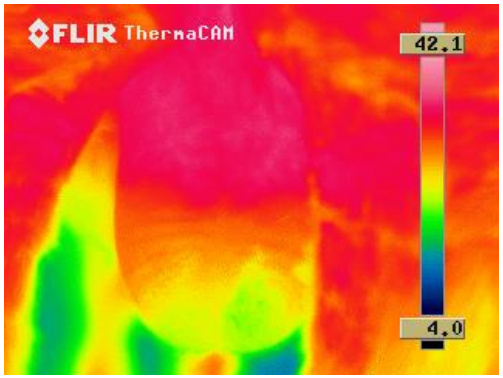
Population 1: R^2 = 0.60
Population 2: R^2 = 0.67
Population 3: R^2 = 0.59

Material & Methods: Blood Parameters

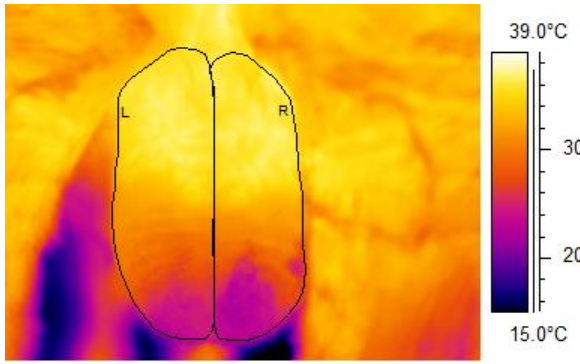
- **Complete blood count (CBC)**
  - **White Blood Cells**
    - **Neutrophils**
    - **Lymphocyte**
    - **Monocyte**
    - **Eosinophil**
    - **Basophil**
  - **Red Blood Cells**
    - **Hemoglobin**
    - **Hematocrit**
    - **Mean Cell Volume**
  - **Proteins**
    - **Total Solutes Protein**
  - **Platelets**

Material & Methods: Scrotum Infrared Thermography

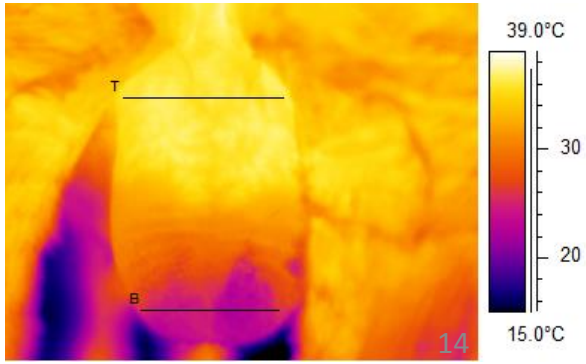
- **Image Collection**
  - ThermaCam SC2000®
- **Image Analysis**
  - ThermaCam Researcher 2001® software



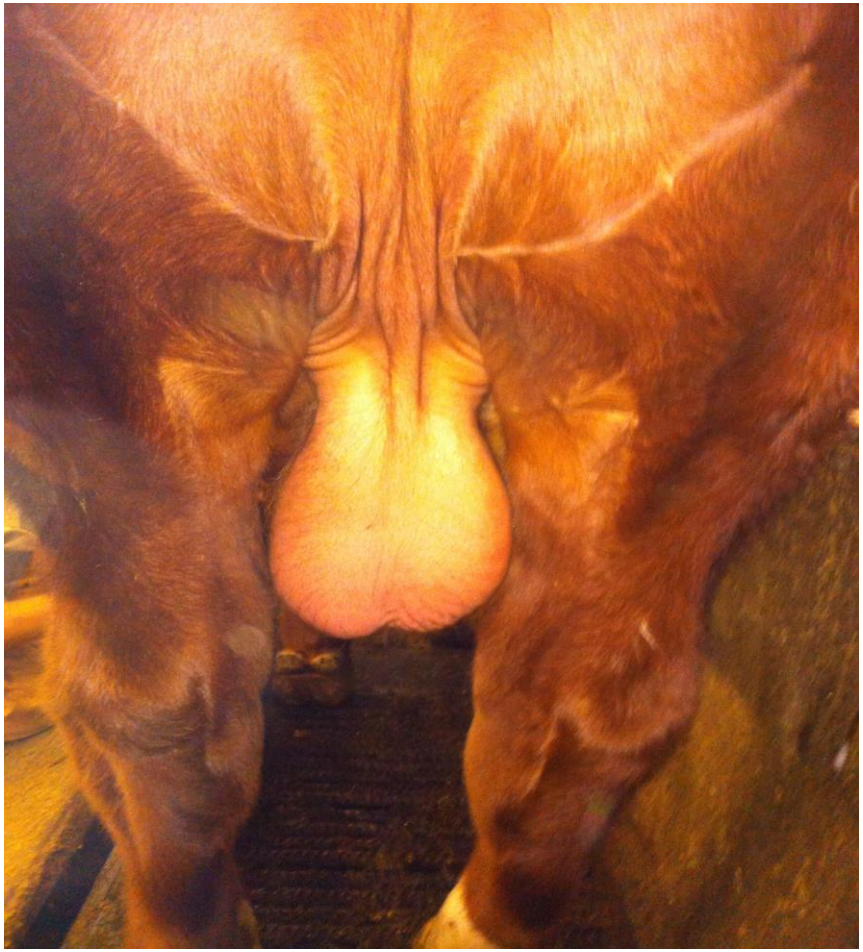
Scrotal Surface Temperature



Scrotal Surface Temperature Base (T) and Apex (B)



Material & Methods: Scrotal Circumference

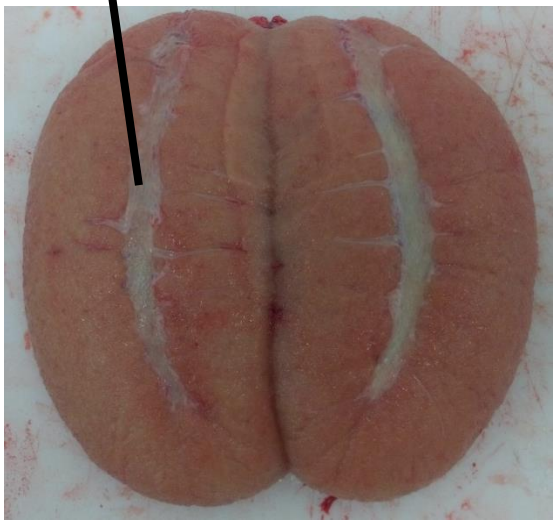


Material & Methods: Testes Ultrasound

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

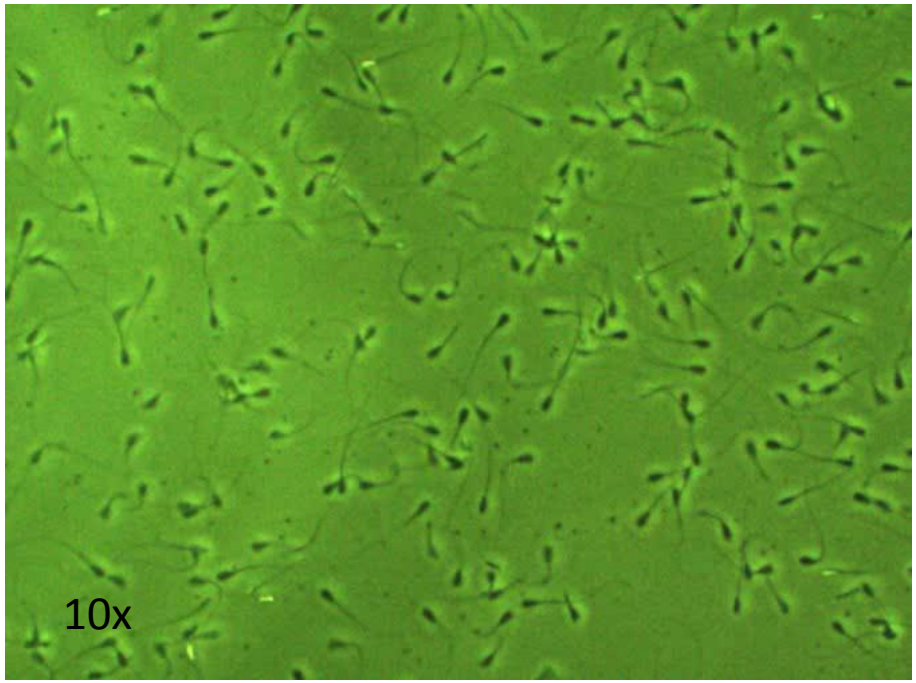
- **Image analysis**
  - Pixel intensity using ImageJ®

Mediastinum



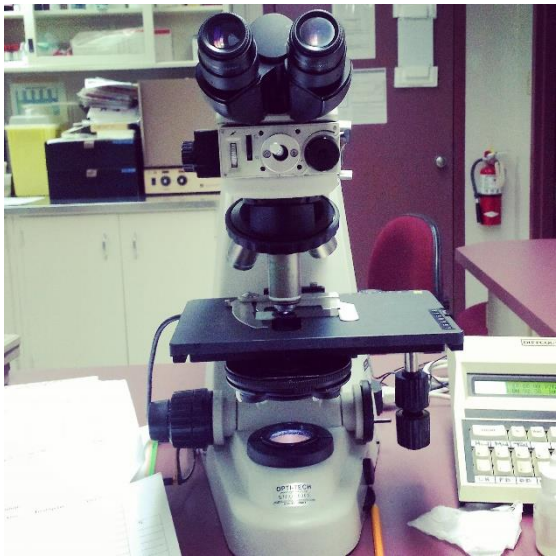
Material & Methods: Semen Quality

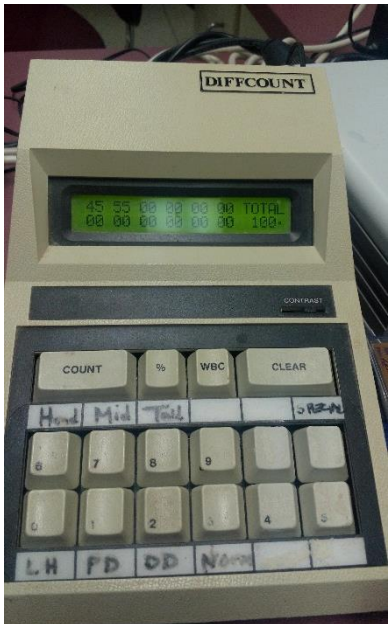
- **Semen collection**
  - Pulsator IV electro ejaculator®
- **Sperm motility (%)**

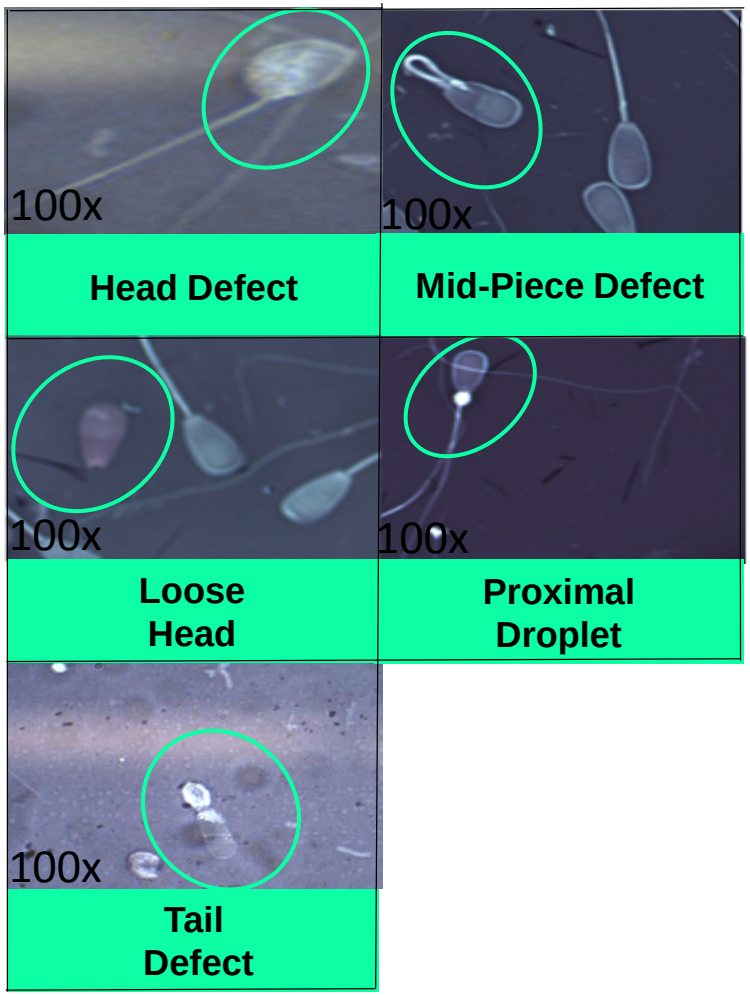


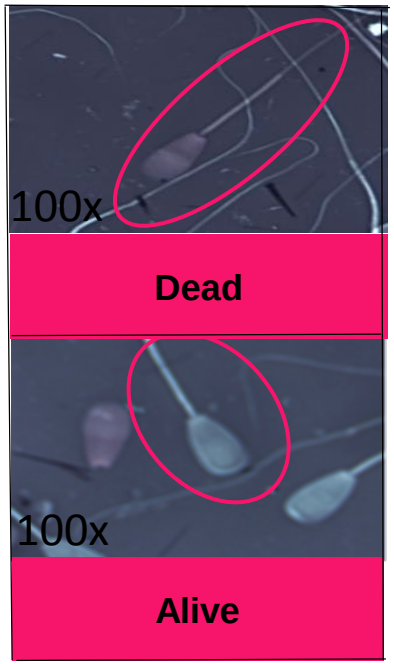
Material & Methods: Semen Quality

Sperm morphology (%) and viability (%)



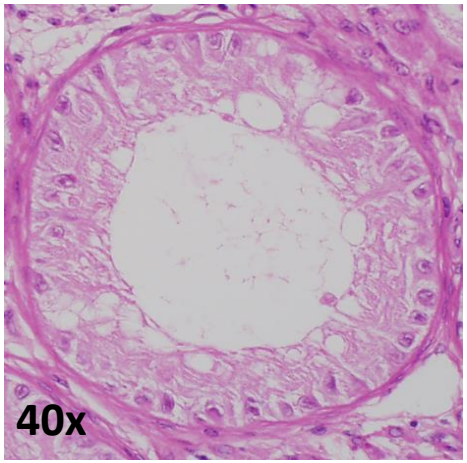




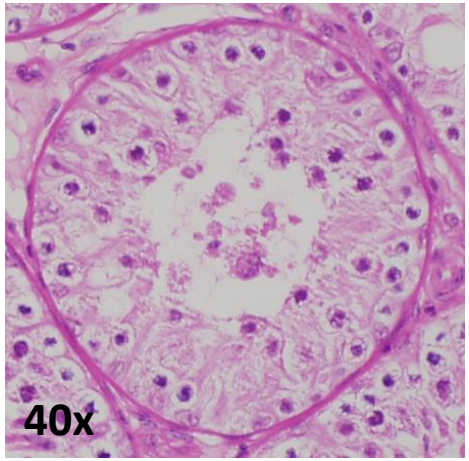


Material & Methods: Testes Assessment

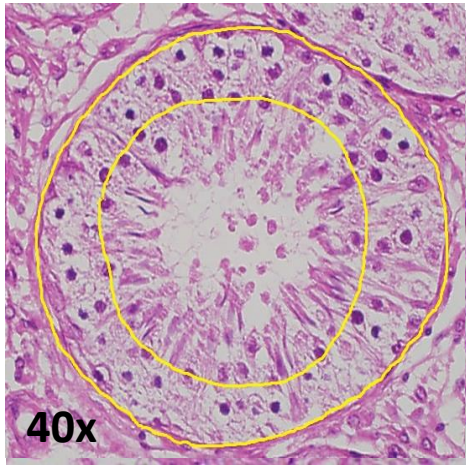
Testes morphology and histology



Immature



Reaching Maturity



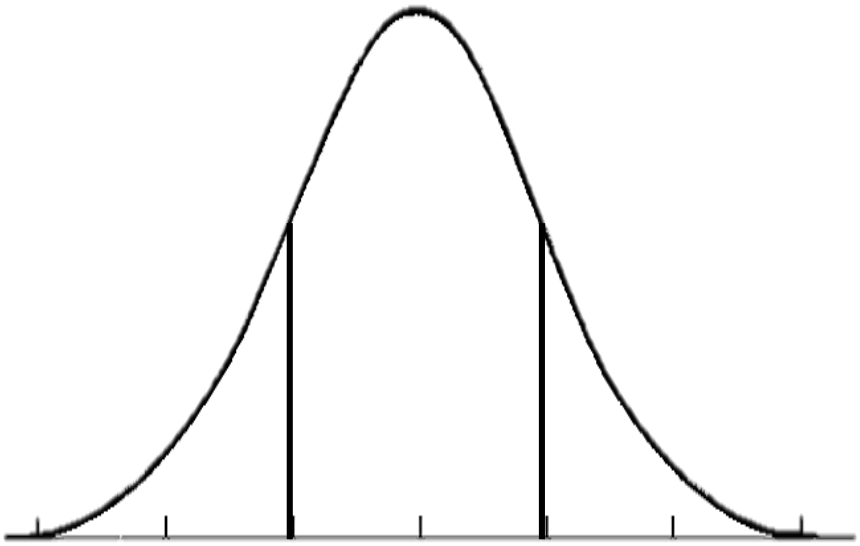
Mature

Classification of tubules (Ahmed and Abdi, 2009)

- Tubule area
- Lumen area

Material & Methods: Statistical Analysis

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



Bottom 25% **Top 25%**

EFFICIENT: -1.89 ± 0.67 kg/day
INEFICIENT: 1.95 ± 0.79 kg/day

General Linear Model

- PROC GLM SAS®

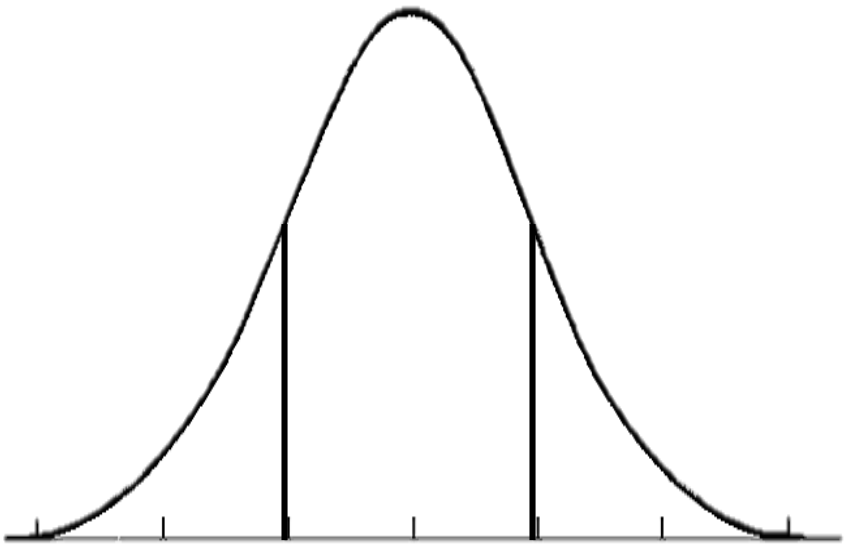
$$Y_{ijkl} = \mu + R_i + B_j + G_k + \beta(A_l) + \varepsilon_{ijkl}$$

Example:

Motility % = μ + Feed Efficiency Class + Breed + Population + Age + Error

Material & Methods: Statistical Analysis

Scrotum infrared thermography and testes ultrasound



Bottom 25% **Top 25%**

EFFICIENT: -1.89 ± 0.67 kg/day
INEFFICIENT: 1.95 ± 0.79 kg/day

General Linear Model

- PROC GLM SAS®

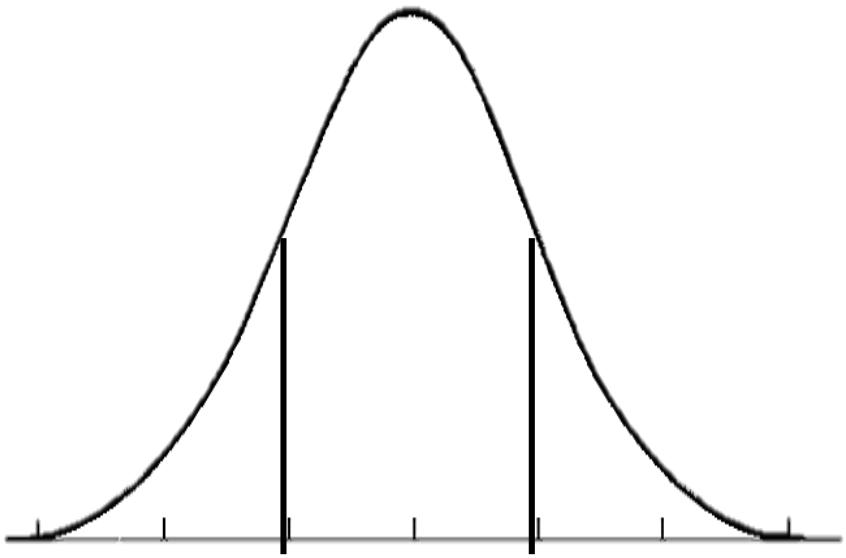
$$Y_{ijklmn} = \mu + R_i + B_j + G_k + \beta(A_{ijkl}) + \delta(T_{ijkm}) + \tau(H_{ijkn}) + \varepsilon_{ijklmn}$$

Example:

Average temperature = μ + Feed Efficiency Class + Breed + Population + Age + Temperature + Humidity + Error

Material & Methods: Statistical Analysis

Repeated testes ultrasound



Bottom 25% **Top 25%**

EFFICIENT: -1.89 ± 0.67 kg/day
INEFFCIENT: 1.95 ± 0.79 kg/day

Mixed Model

- PROC Mixed SAS®

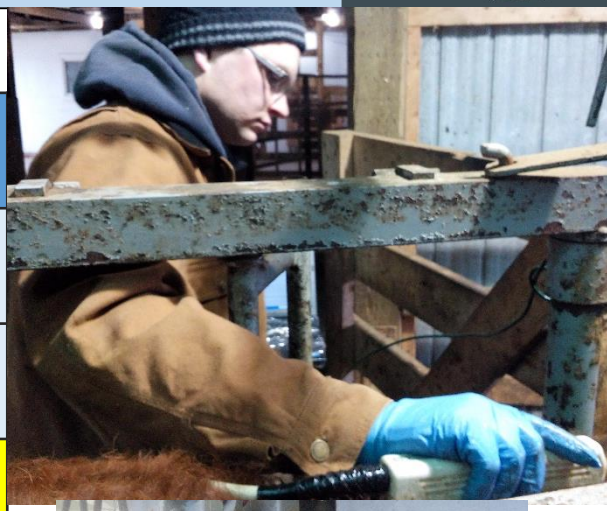
$$Y_{ijklmno} = \mu + R_i + B_j + G_k + \beta(A_{ijkl}) + \delta(T_{ijkm}) + \tau(H_{ijkn}) + \eta(D_{ijko}) + \varepsilon_{ijklmno}$$

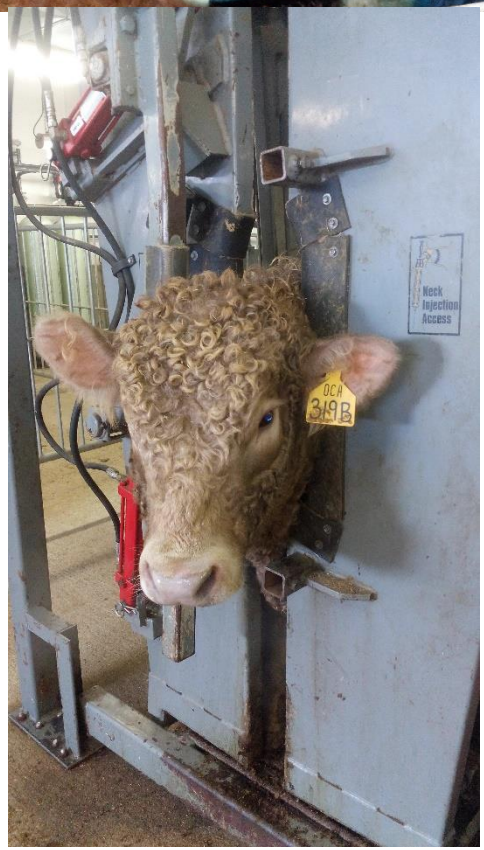
Example:

Mean pixel intensity = μ + Feed Efficiency Group + Breed Group + Population Group + Age + Temperature + Humidity + Date + Error

Results & Discussion: Performance Evaluation

Parameters	Efficient	Inefficient	P-values
Age (days)	403	397	N.S.
Final Body Weight (kg)	480	486	N.S
Average Feed Intake (kg/day)	16.81	20.52	<0.05
Average Daily Gain (kg/day)	1.81	1.88	N.S
Final Back Fat (mm)	4.11	4.18	N.S.
Final Ribeye Area (cm^2)	76.05	78.40	N.S.
Final Rump Fat (mm)	3.92	3.87	N.S.
Final Marbling (Score: 1-10)	6.45	6.32	N.S.
Residual Feed Intake (kg/day)	-1.99	1.78	<0.05



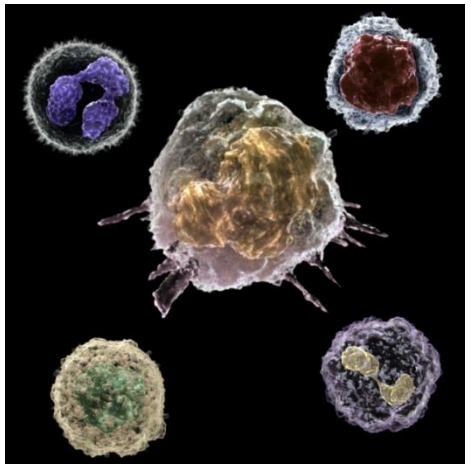


Results & Discussion: Complete Blood Count

CBC parameters	Efficient	Inefficient	P-value
White Blood Cells (x10^9/L)	9.42	8.50	<0.05
Neutrophils (x10^9/L)	3.27	4.04	N.S.
Lymphocytes (x10^9/L)	4.70	4.23	N.S.
Monocytes (x10^9/L)	0.54	0.30	<0.10
Eosinophils (x10^9/L)	0.33	0.11	<0.10
Basophils (x10^9/L)	0.11	0.13	N.S.
Red Blood Cells (x10^{12}/L)	8.50	8:37	N.S.
Hemoglobin (g/L)	129.81	128.36	N.S.
Hematocrit (L/L)	0.35	0.35	N.S.
Mean Cell Volume (fL)	40.88	41.35	N.S.
Platelets (x10^9/L)	352.21	331.39	N.S.
Total Solute Protein (g/L)	74.24	72.03	N.S.

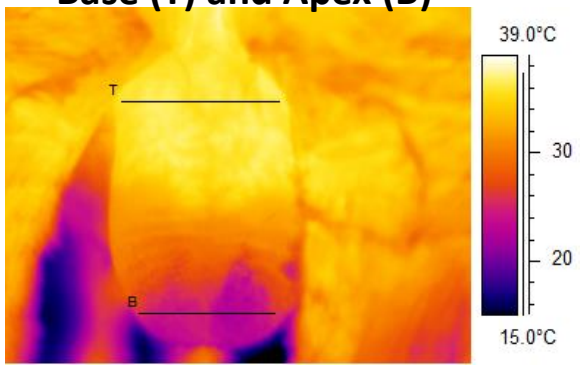
Higher white blood cells in efficient steers
(Richardson et al., 2002)

Lower neutrophils and higher lymphocytes in efficient heifers
(Crane et al., 2015)

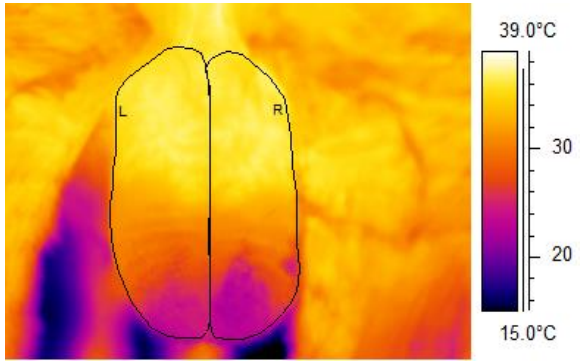


Results & Discussion: Scrotum Infrared Thermography

Scrotal Surface Temperature Base (T) and Apex (B)



Scrotal Surface Temperature



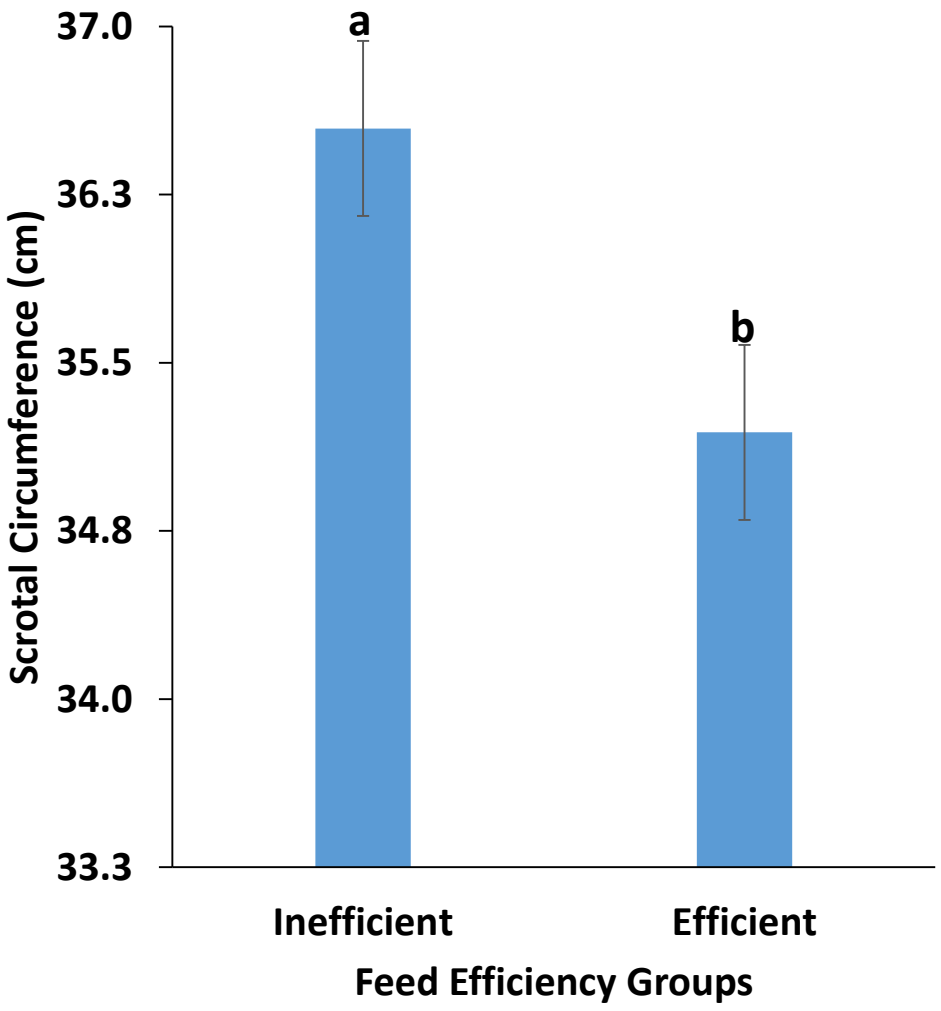
Infrared Parameter	Efficient	Inefficient	P-Value
Base Average Temperature	31.76	32.87	<0.05
Base Maximum Temperature	33.49	34.16	N.S.
Base Minimum Temperature	28.91	30.50	<0.05
Base Standard Deviation	0.99	0.72	<0.05
Apex Average Temperature	24.67	25.14	N.S.
Apex Maximum Temperature	26.49	27.26	N.S.
Apex Minimum Temperature	21.64	22.09	N.S.
Apex Standard Deviation	0.99	1.20	N.S.
Base – Apex Average Temperature	7.10	7.73	N.S.
Average Scrotum Temperature	28.48	29.54	<0.05

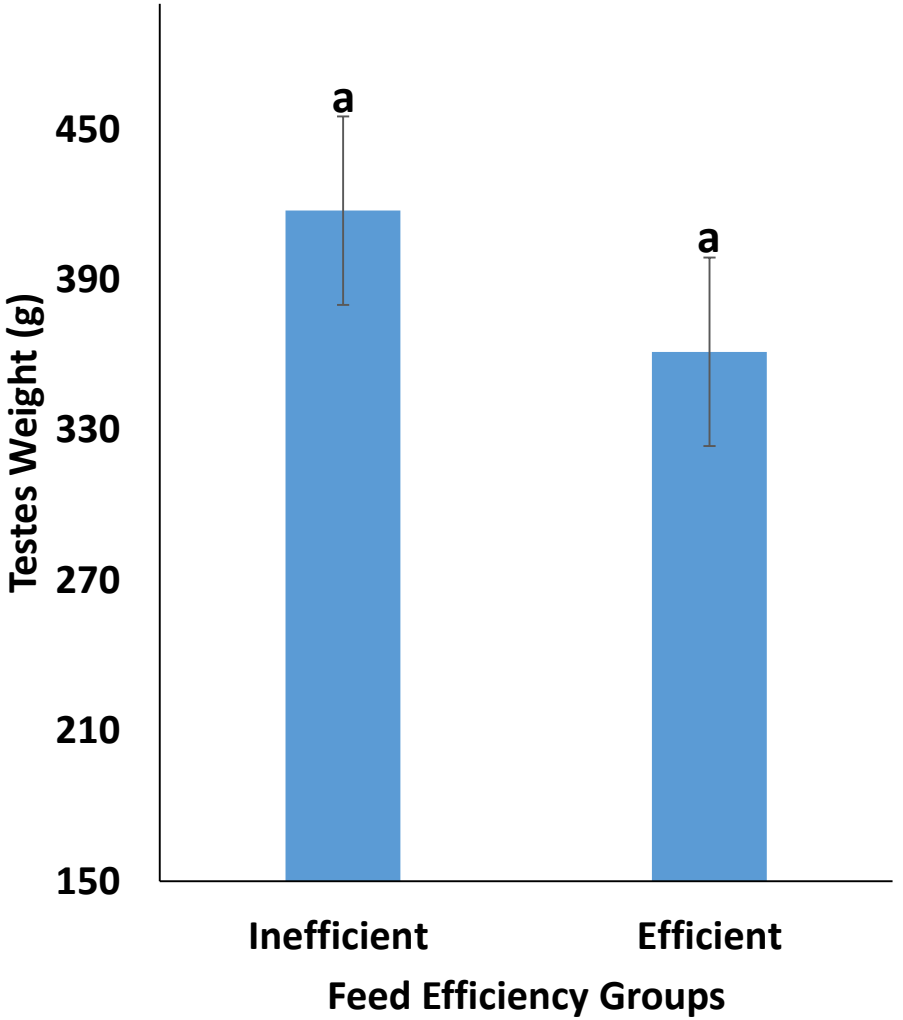
Difference in temperature variation at base of the scrotum
(Fontoura et al., 2015)

→

Efficient bulls have decreased testicular heat dissipation

Results & Discussion: Scrotal Circumference & Testes Weight

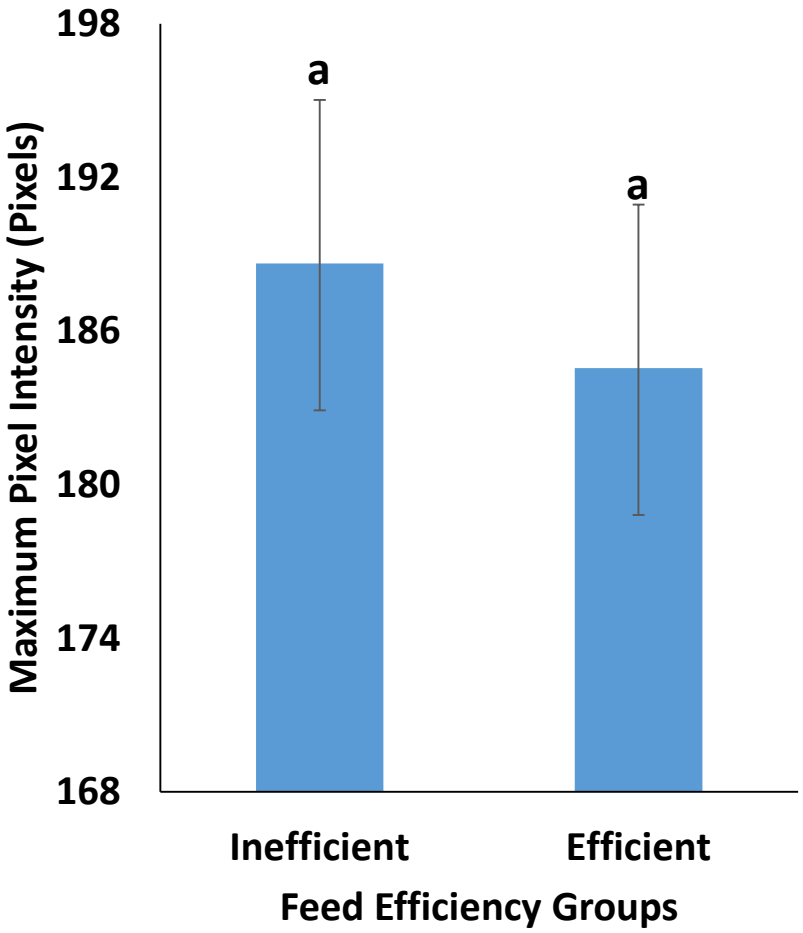


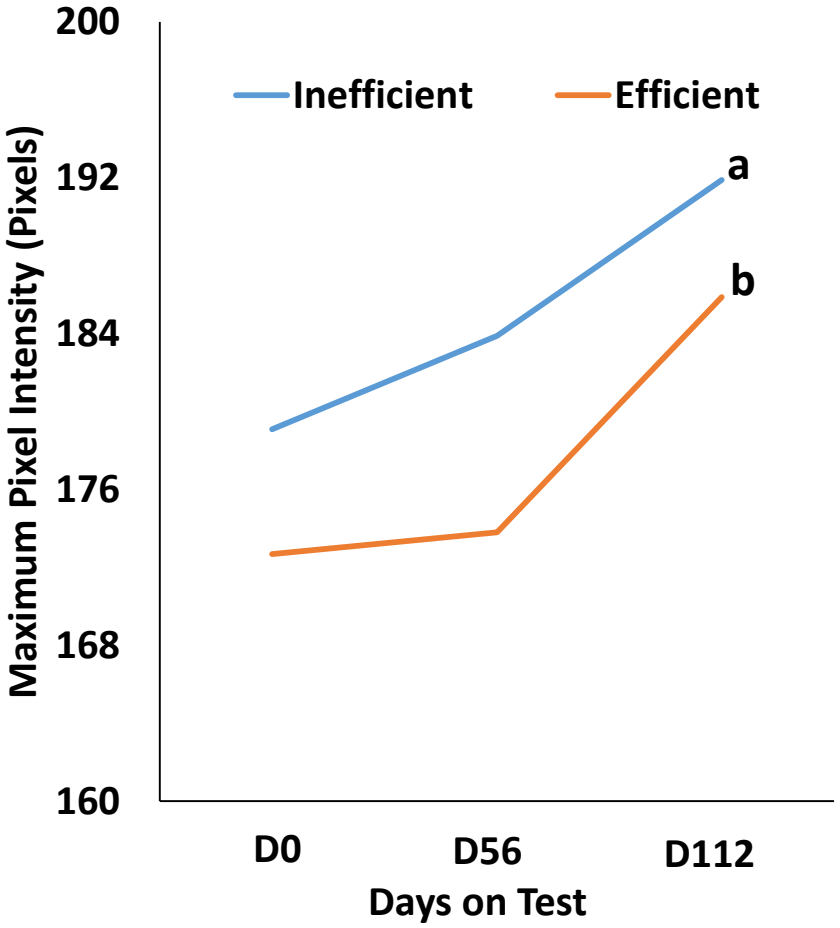


No difference in scrotal circumference between efficiency groups
(Hafla et al., 2012; Wang et al., 2012; Fontoura et al., 2015)

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

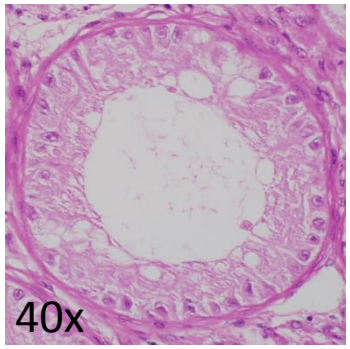
Results & Discussion: Semen Quality

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

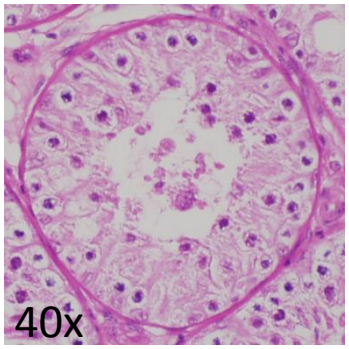
Lower sperm motility
(Wang et al., 2012; Awda et al., 2012;Fontoura et al., 2015)
No difference between efficiency class
(Hafa et al., 2012)

Higher sperm abnormalities
(Hafla et al., 2012; Fontoura et al., 2015)
No difference between efficiency class
(Wang et al., 2012; Awda et al., 2012)

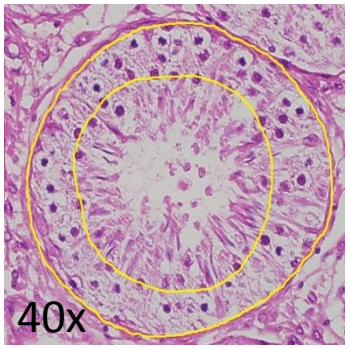
Results & Discussion: Testes Histology



Immature



Reaching Maturity



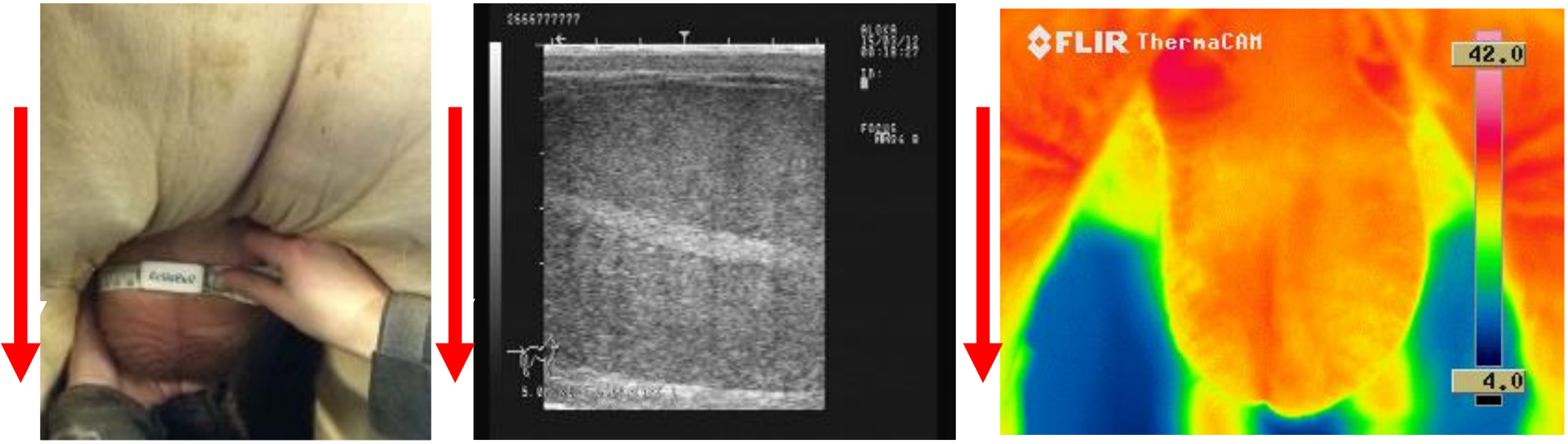
Mature

Seminiferous Tubules Parameters	Efficient	Inefficient	P-Value
Tubule Area (mm^2)	189.23	182.21	N.S.
Lumen Area (mm^2)	70.28	71.57	N.S.
Mature (%)	96.56	95.66	N.S.
Reaching Maturity (%)	2.04	2.33	N.S.
Immature (%)	0.04	0.31	N.S.

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

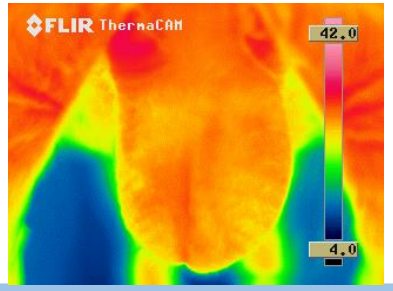
(Fontoura et al., 2015)

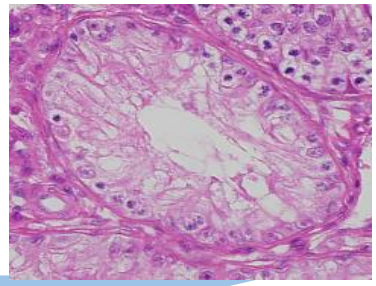
Conclusion



Efficient bulls = less developed testes → lower scrotal temperature

Conclusion





?

Testicular Function

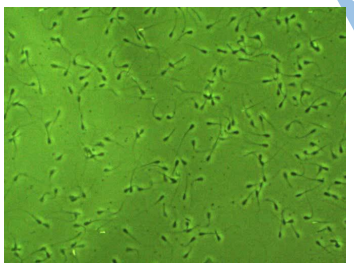
?

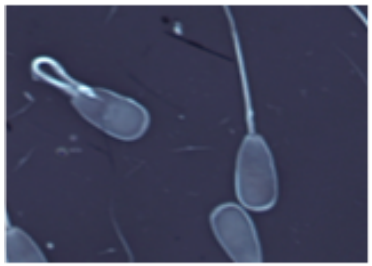
RFI

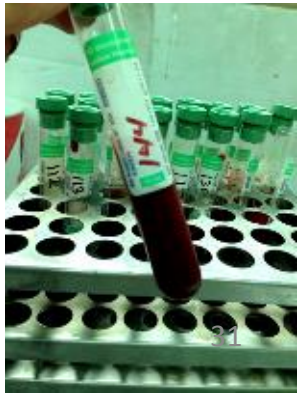
Semen Quality

Metabolism

?







Future Directions

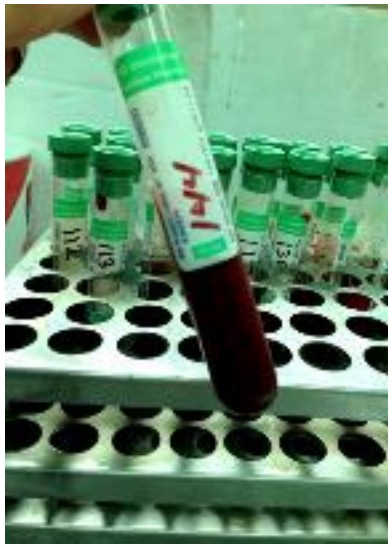
- **Sexual organs histology**

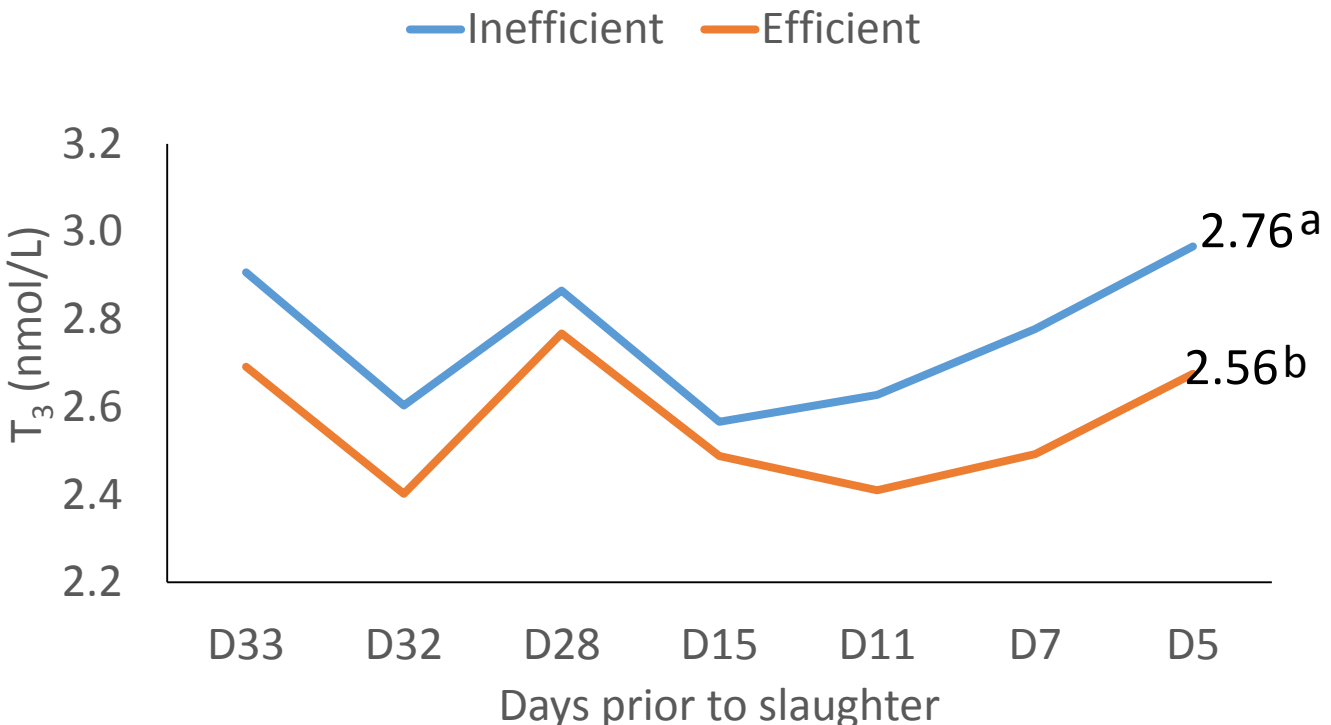
Seminal Vesicles

Epididymis

Vascular Cone

- **Metabolic and sexual hormones**





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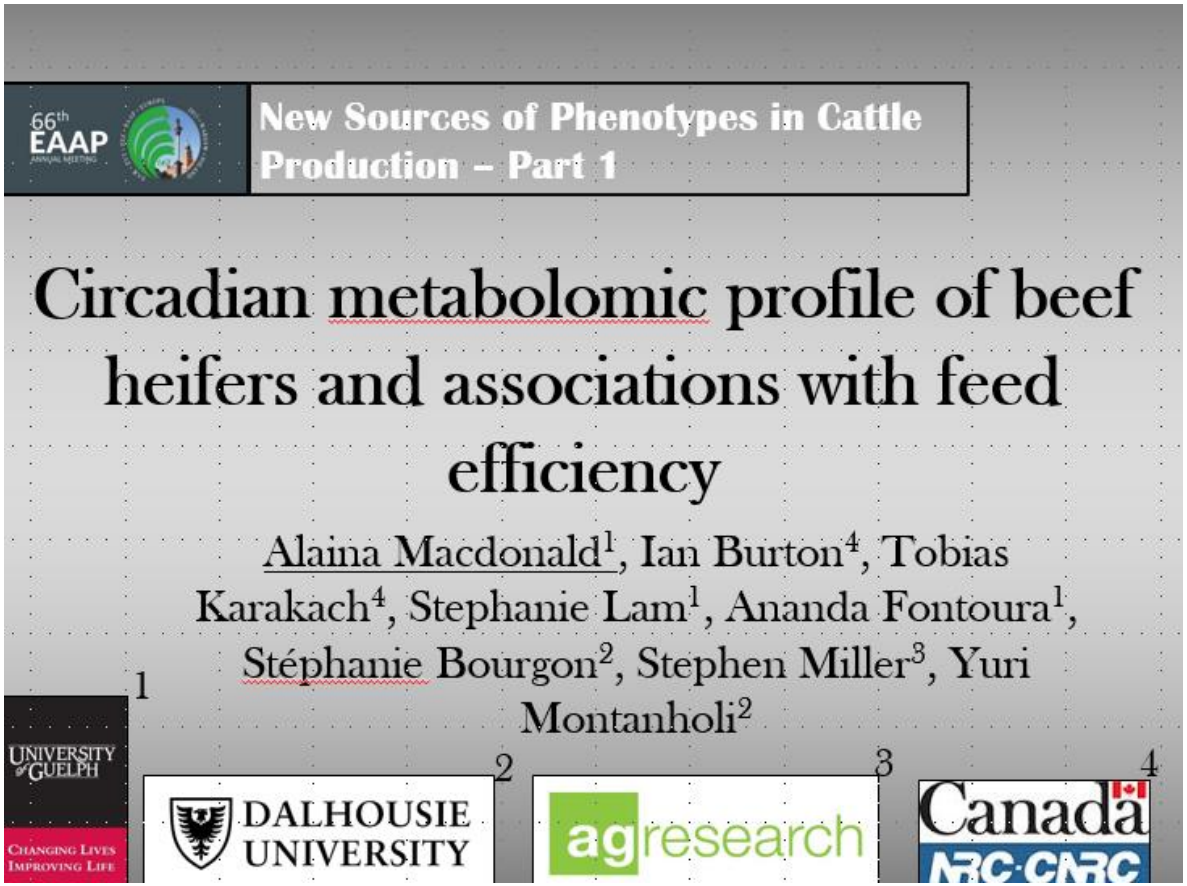

Session 27: New sources of phenotypes in cattle production – Part 1

9:30AM