

Associations of rumen structure, function, and microbiology with feed efficiency in beef cattle

Stephanie Lam¹, Jasper Munro², John Cant¹, Lelou Guan³, Michael Steele³, Stephen Miller^{1,4}, Yuri Montanholi^{1,2}





- Introduction
- Hypothesis and Objectives
- Materials and Methods
- Results and Discussion
- Conclusion
- Acknowledgements

Introduction



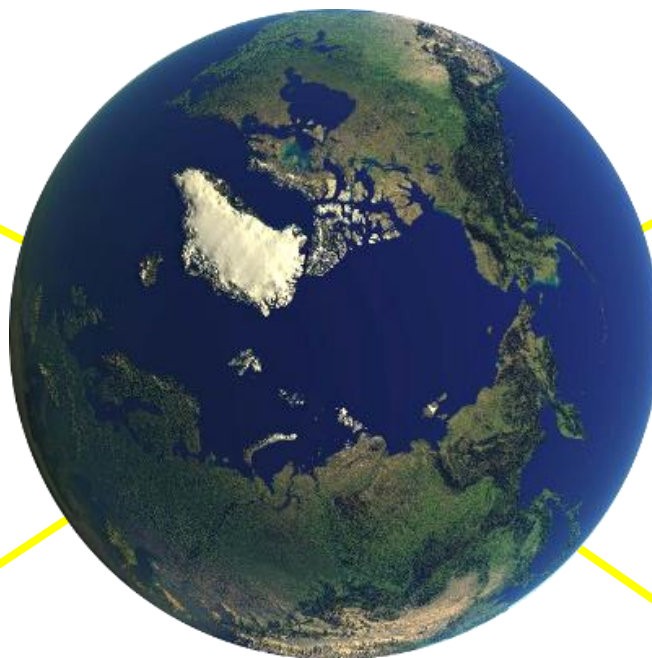
Feed Efficiency



Residual Feed Intake (RFI)



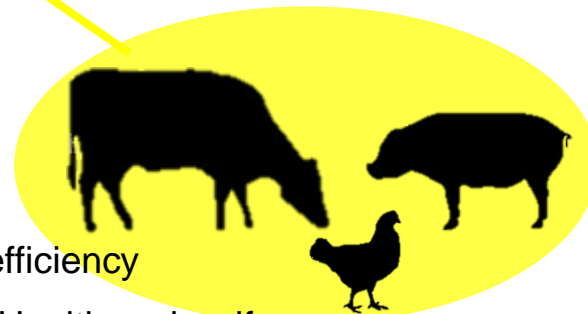
Rising feed and production costs



Environmental footprint



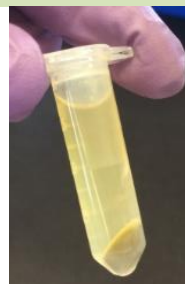
Resource efficiency



Production efficiency

Health and welfare

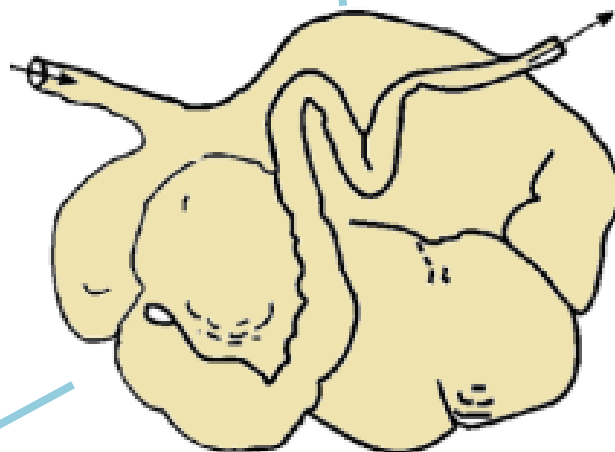
Introduction



Microbial ecology

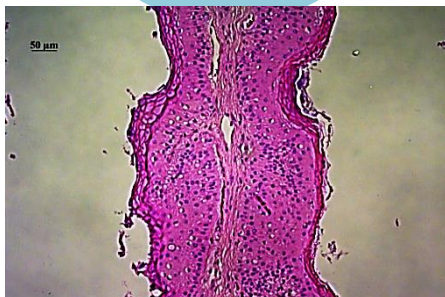


VFA concentration

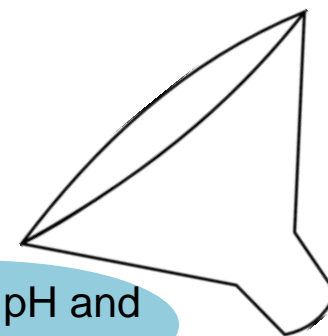


Rumen

Rumen epithelium



Ruminal pH and temperature



Hypothesis



- Large energy sink
- Energy absorption (~75% VFA)
- Rumen = 70% total GIT mass (Baldwin 1998)
- Variation in microbiota and VFA absorption (Khiaosa-ard 2014)

Due to energetic processes involved in the efficiency of feed utilisation, these ruminal parameters are associated with feed efficiency.

Objectives



Low-RFI
(Efficient)

V.S

High-RFI
(Inefficient)

pH and temperature

Microbial ecology

VFA concentration

Tissue morphology

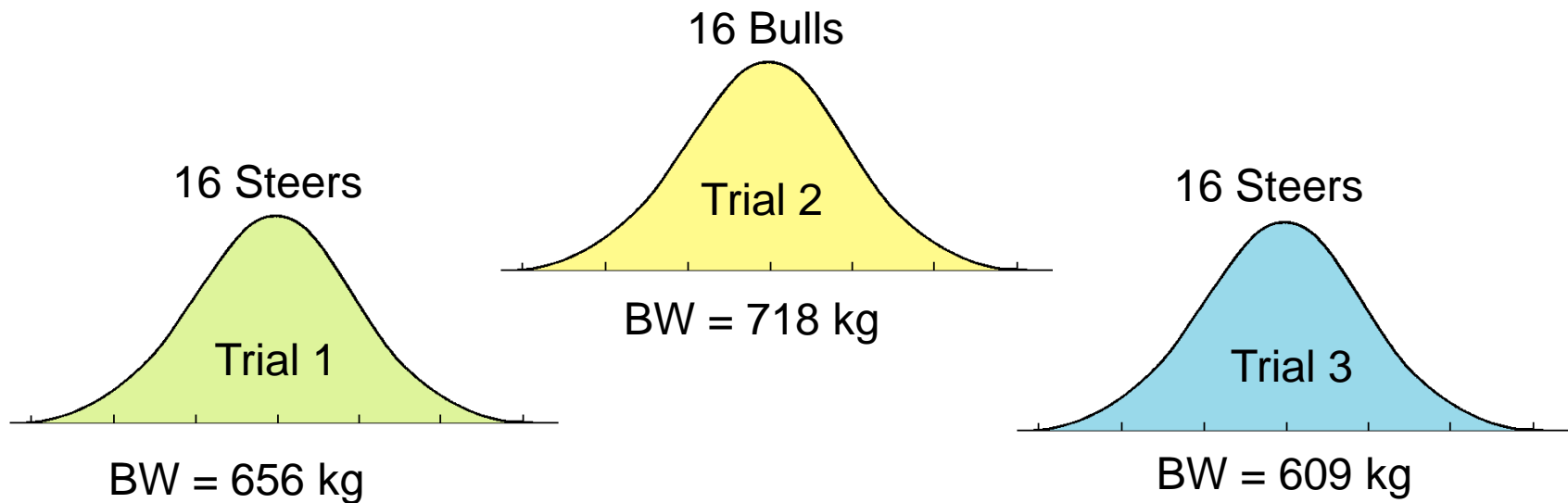
To evaluate ruminal pH and temperature, VFA concentration, microbial ecology, and papillae epithelium thickness and to characterize that in the context of feed efficiency.

Materials: experimental conditions



48 crossbred beef cattle

Breed composition: Simmental, Angus, Piedmontese, Gelbvieh



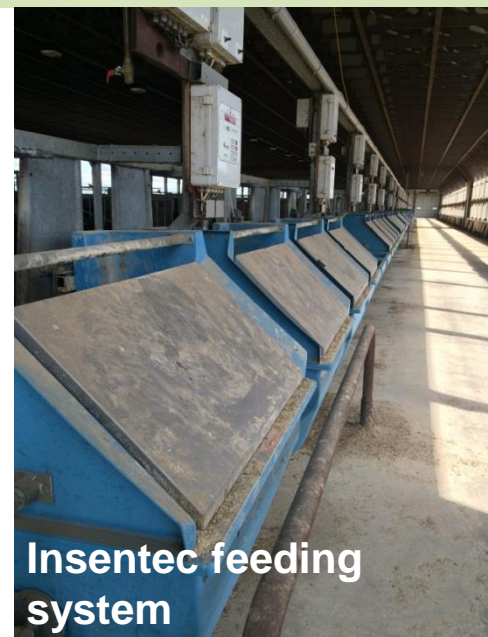
Materials: diet composition



<i>Chemical Composition</i>	<i>Dry Basis (%)</i>
Dry Matter	48.42
Crude Protein	12.20
Acid Detergent Fibre	10.69
Neutral Detergent Fibre	19.30
Crude Fat	2.90
Starch	45.01
Minerals	4.58
Total Digestible Nutrients	86.14

<i>Ingredient Composition</i>	<i>Dry Basis (%)</i>
High-moisture corn	78.0
Haylage	14.0
Soybean meal	5.0
Premix*	3.5

*Contains 40% of calcium phosphate, 60% trace mineralized salt



Methods: RFI calculation and model



$$\text{Feed intake} = \mu + \beta_1 \times (\text{body weight}) + \beta_2(\text{ADG}) - \beta_4 (\text{ribeye area}) + \beta_3 (\text{back fat}) + \beta_5 (\text{rump fat}) - \beta_6 (\text{marbling})$$

Body Size *Rate of Gain* *Leanness*

Fatness

Trial	R ²
1 st Steer population	0.50
Bull population	0.60
2 nd Steer population	0.71

Methods: experimental period



Methods: rumen bolus insertion



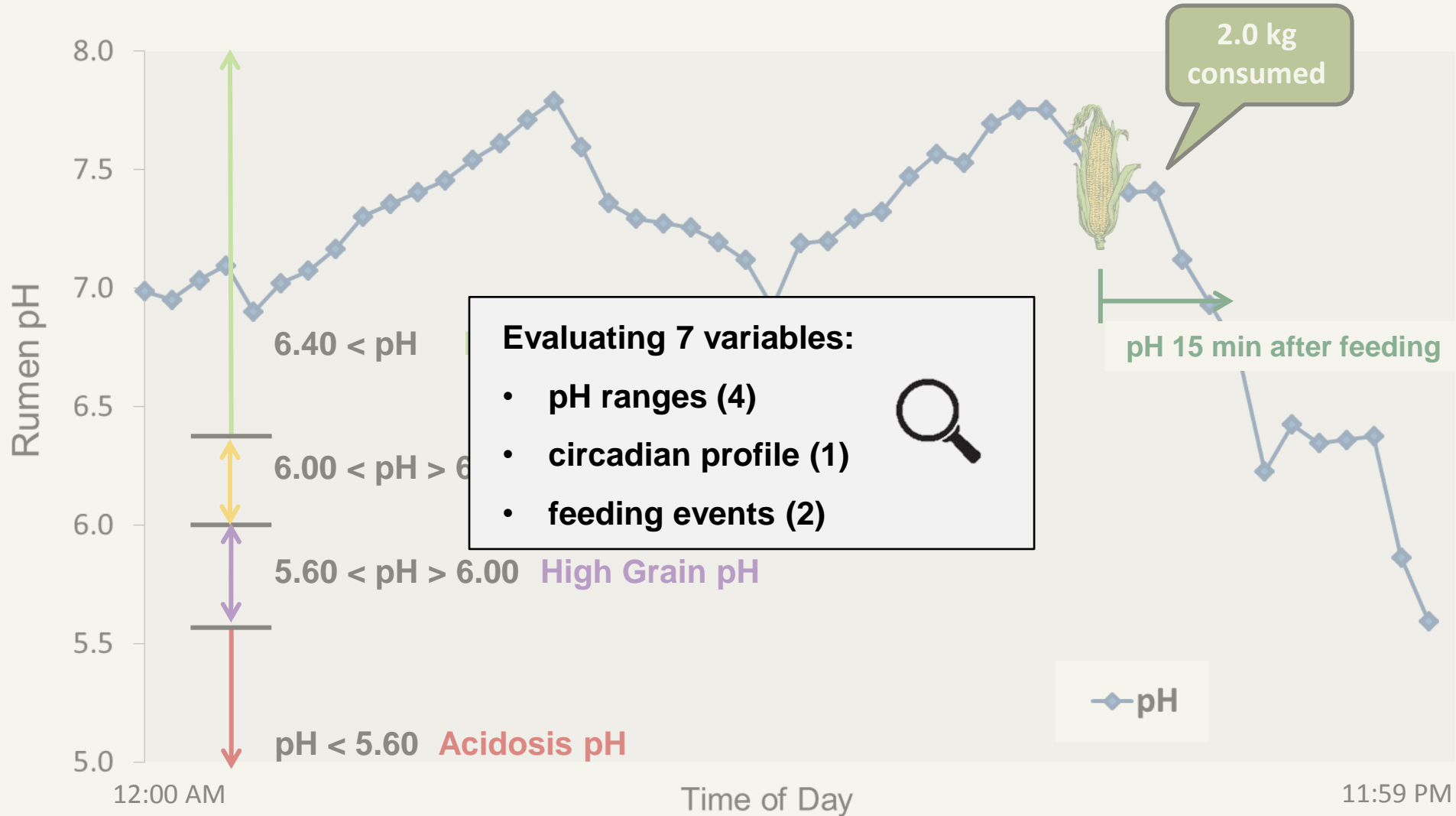
Rumen-boluses:

T9 LRCpH Data Logger
Dascor®

Recording:

5 minute intervals (~2600
data points/animal)

Methods: pH and temperature



Methods: rumen fluid collection



Collection: ~7 days prior slaughter and at slaughter

Method: Esophageal tubing and filtering



Evaluating:

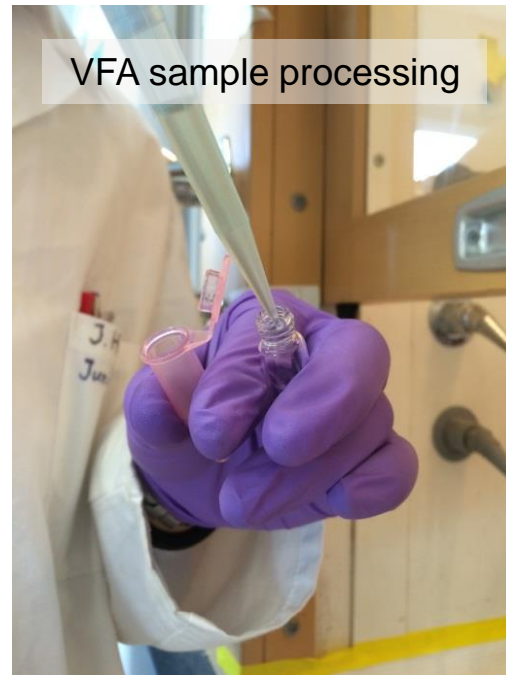
- microbial ecology
- volatile fatty acids profile



Methods: VFA concentration



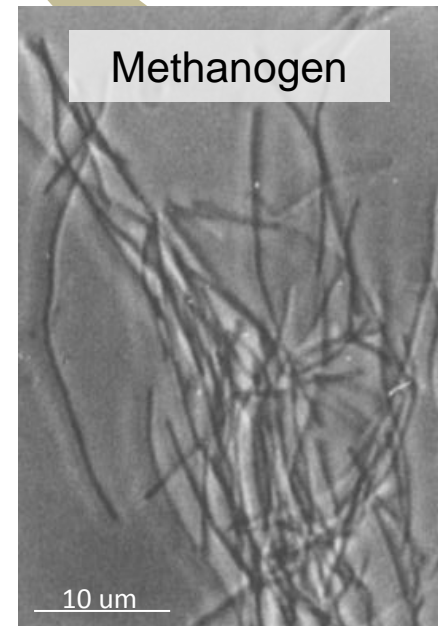
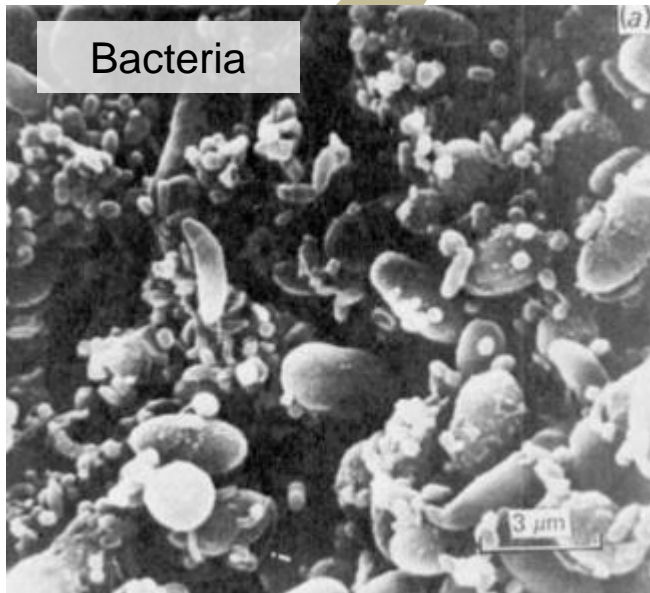
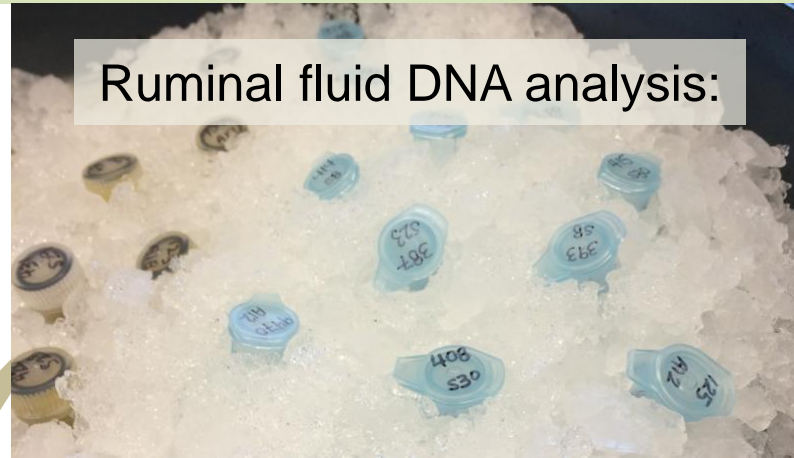
- Gas chromatography
 - Total VFA
 - Acetic acid
 - Butyric acid
 - Propionic acid
 - Isobutyric acid
 - Isoproionic acid
 - Valeric acid
 - Capronic acid



Methods: microbial ecology



- DNA isolation
- RT Q-PCR



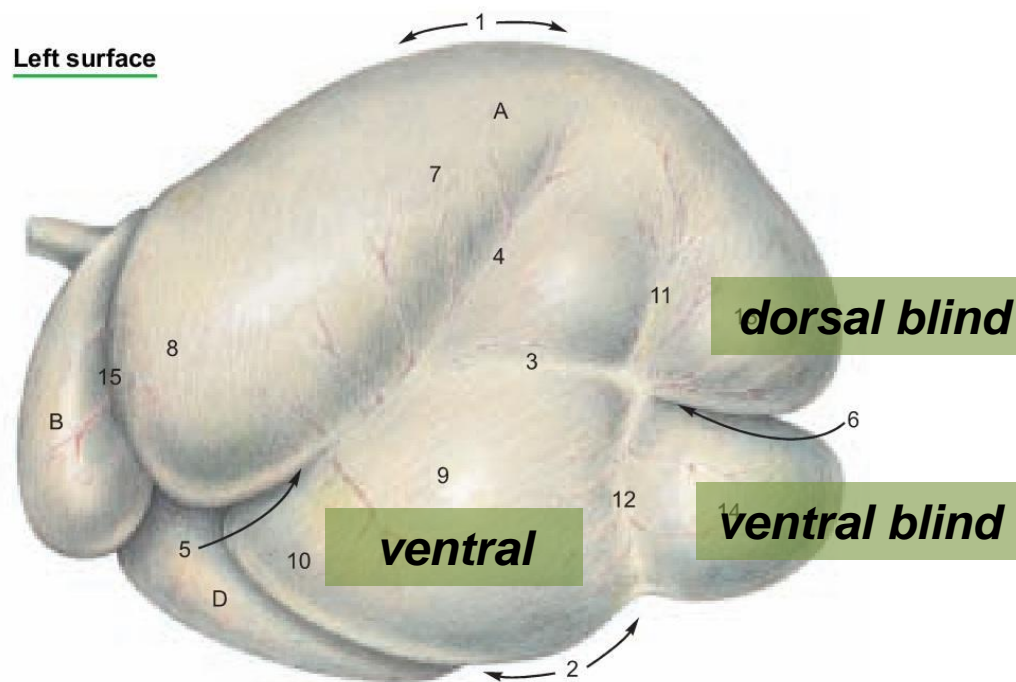
(Doddema 1978; Mathers and Miller 1980; Godfried 1980)

Methods: tissue collection



Evaluating:

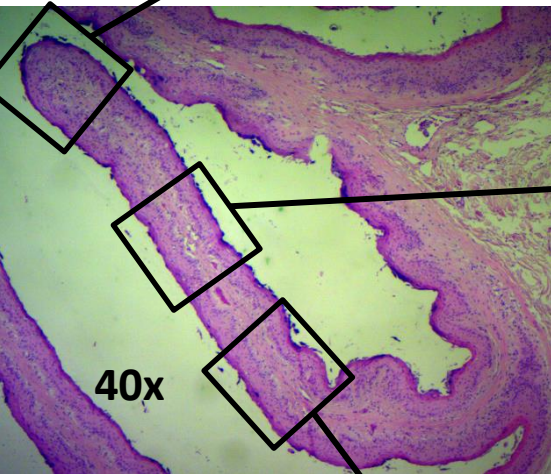
- Epithelial thickness



Methods: microscopy

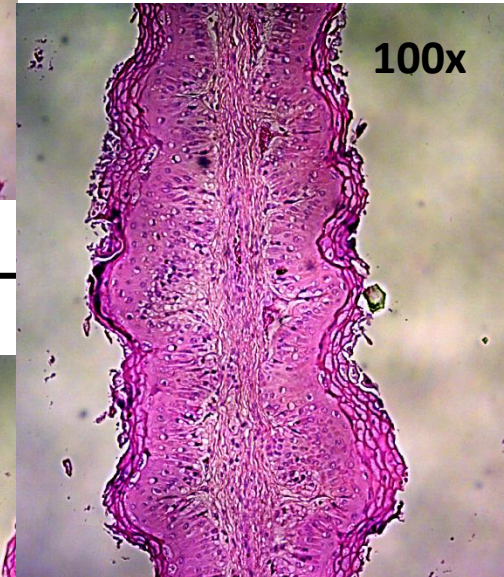


Tip



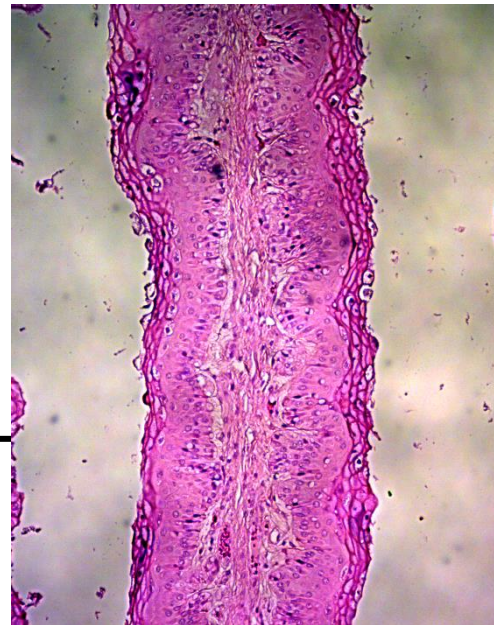
40x

100x



Mid-piece

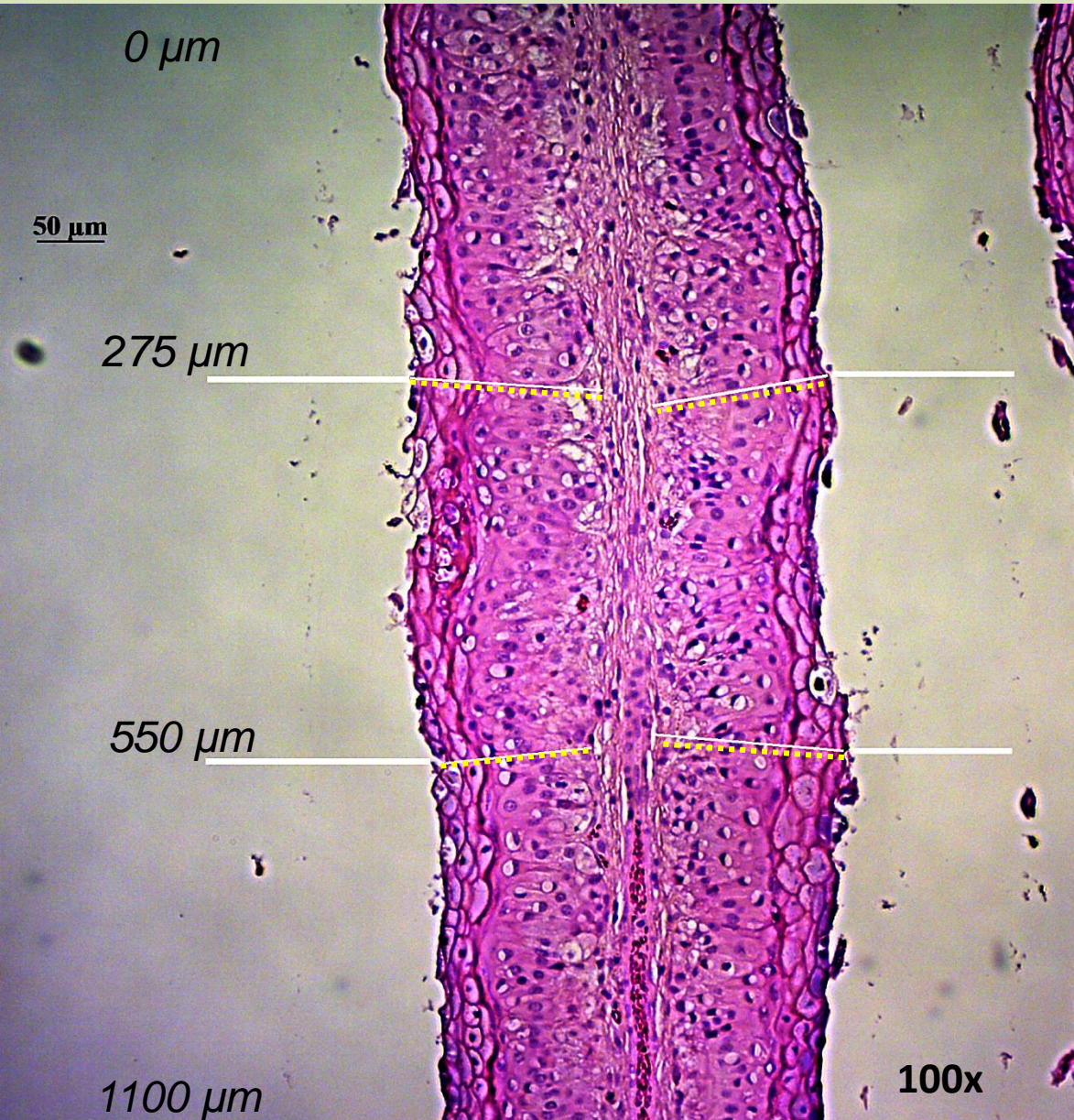
Base



Measure:

- 10 papillae/slide
- 3 chambers

Methods: tissue microscopy



- Evaluated:
Papillae epithelium
thickness from **connective
tissue to stratum corneum**
- Mid piece micrograph
- 4 - measurements



Current work:

– stratum epithelium layers:

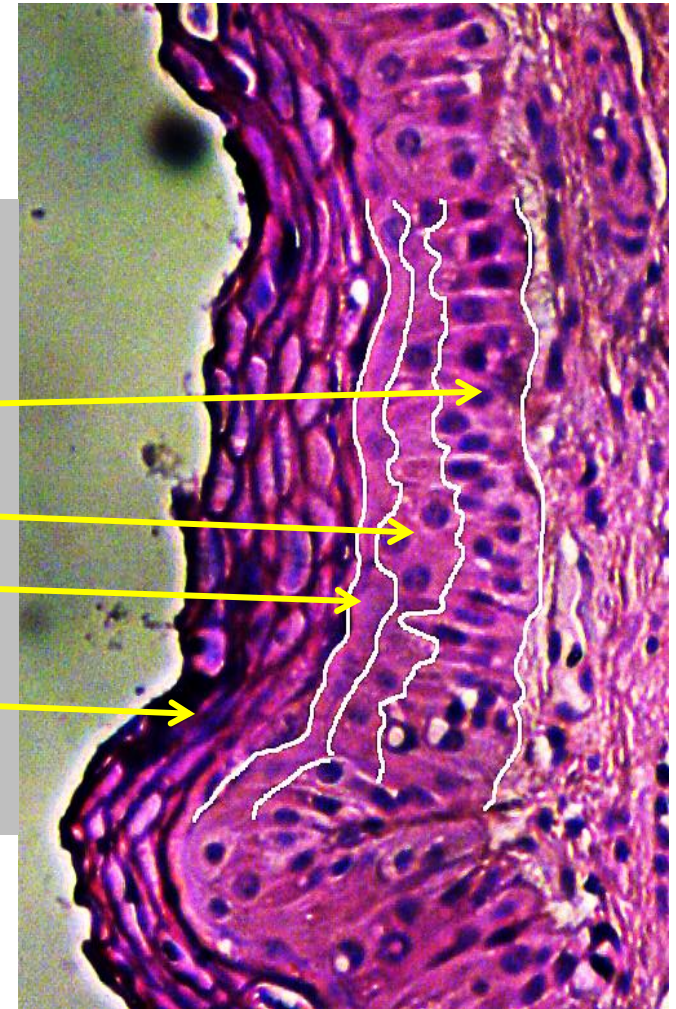
• stratum **basale**

• stratum **spinosum**

• stratum **granulosum**

• stratum **corneum**

– Cell number and width (μm)

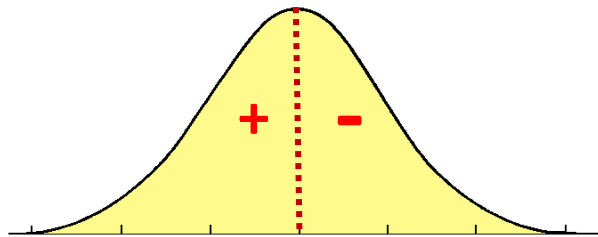


Methods: statistical analysis

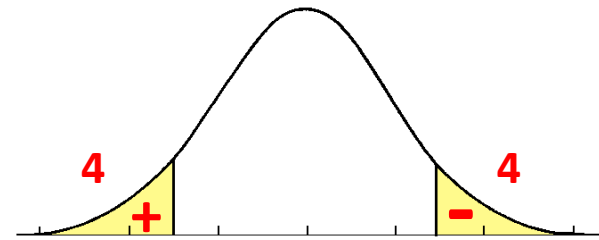


Univariate Normality Procedure

- Skewness, Kurtosis, Anderson-Darling
- Transformations (E^x , $\log(X)$, $\sin(X)$)



50% Efficient vs. 50% Inefficient



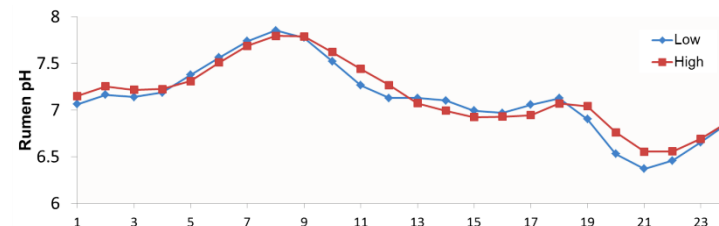
8% Efficient vs. 8% Inefficient

General Linear Model Procedure

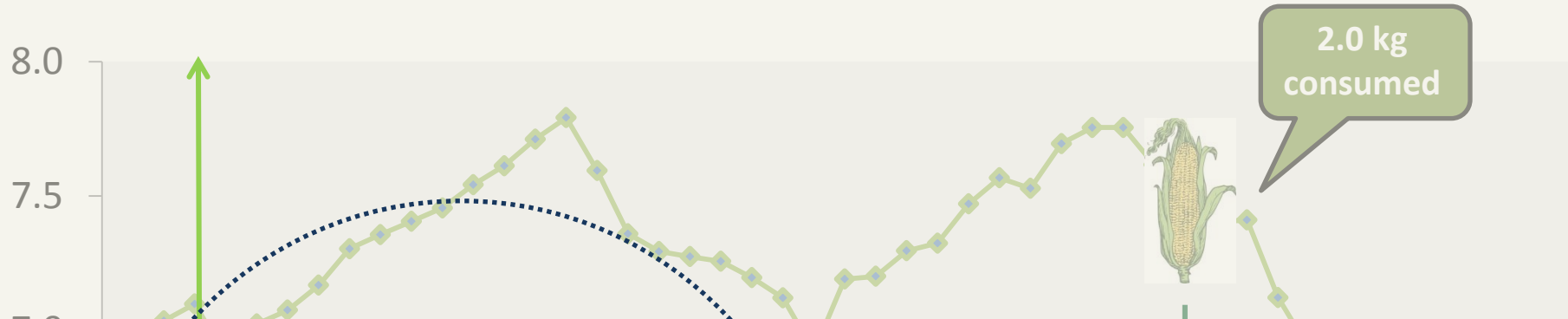
- pH ranges
- pH during and after feeding
- Microbial ecology
- VFA concentration
- Papillae thickness

Mixed Procedure

- pH and temperature circadian profile



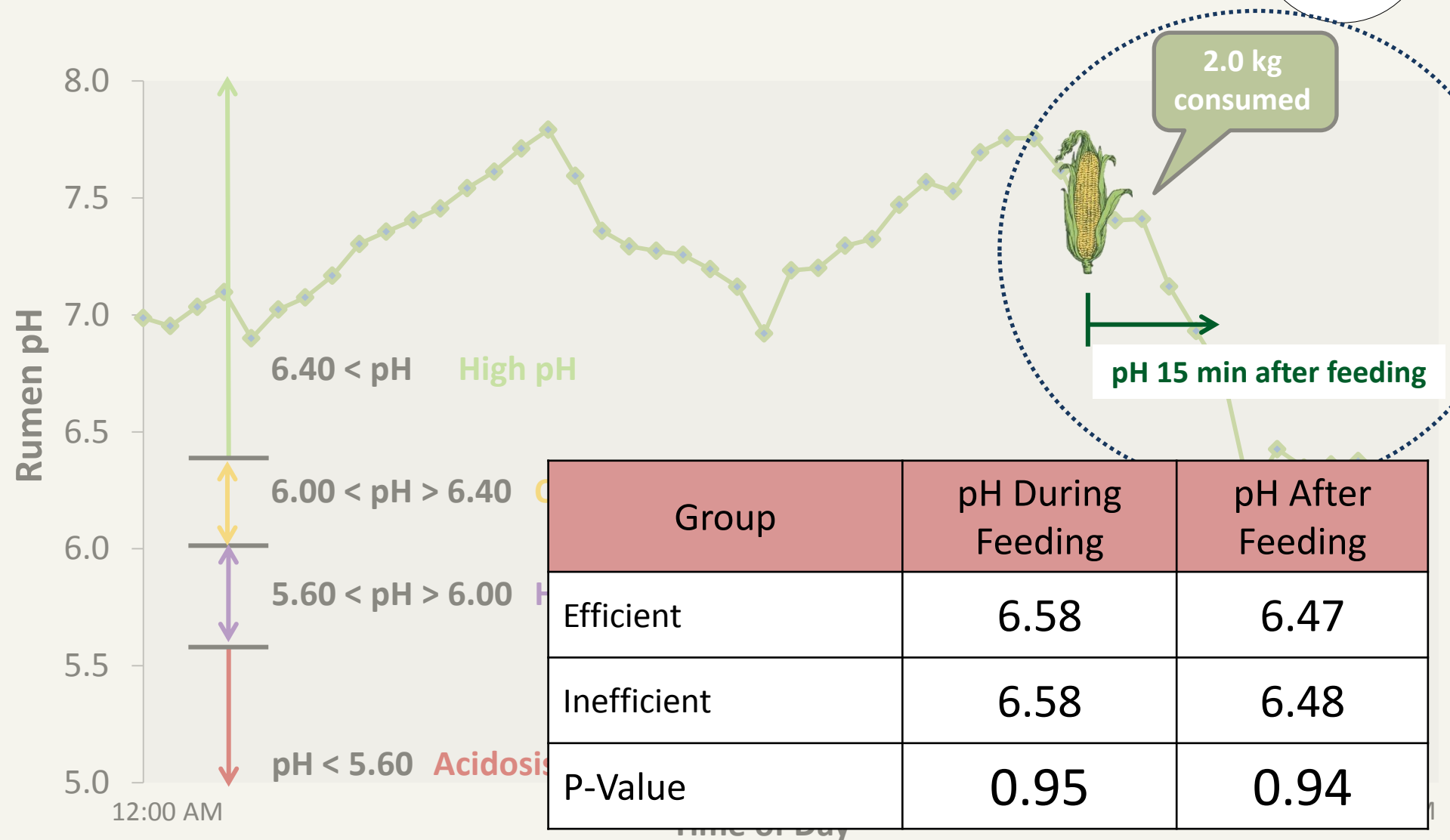
Results and Discussion: pH and temperature



Rumen Condition	pH Range	% Time in range		P-value
		Efficient	Inefficient	
Acidosis pH	pH < 5.60	2.43	2.25	0.86
High-grain diet reference	5.60 < pH > 6.00	4.68	5.88	0.45
Optimal digestion	6.00 < pH > 6.40	12.27	14.20	0.38
High pH	pH > 6.40	77.59	76.67	0.38

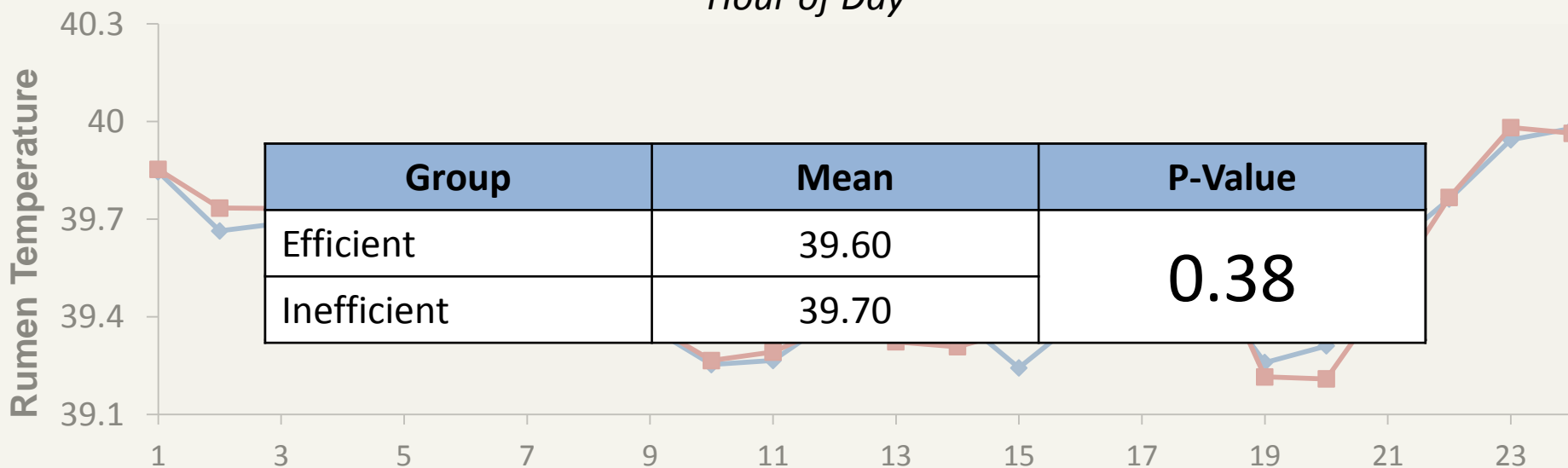
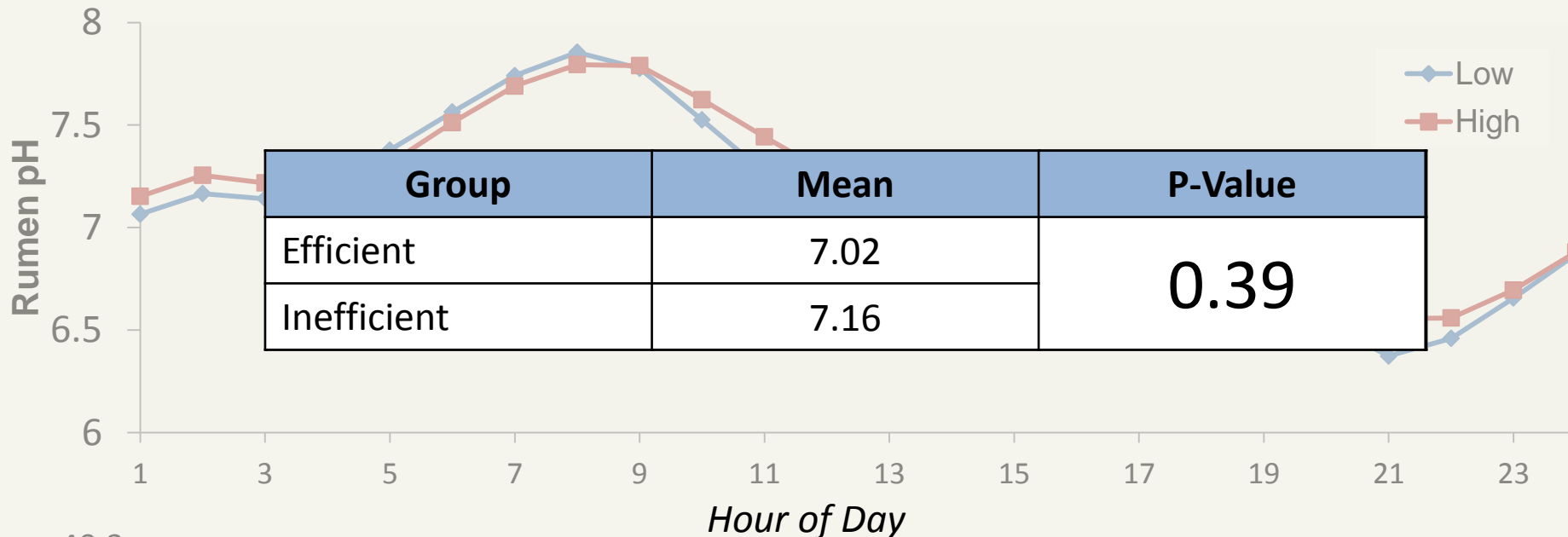
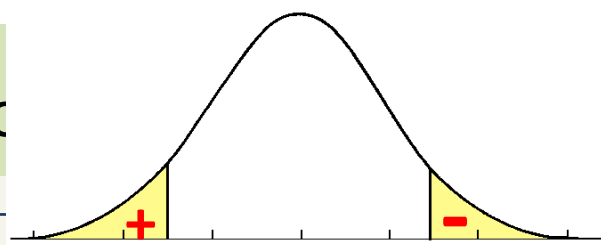
12:00 AM Time of Day 11:59 PM

Results and Discussion: pH and temperature





Circadian pattern



Results and Discussion: pH and temperature



↑ Efficiency = ↑ Ruminal pH

Pregnant beef cows with low- and high-RFI.

	Diet	Efficient	Inefficient	P-value
Fitzsimmons et al. 2014	Haylage	6.77	6.98	0.01
Lawrence et al. 2013	Grass silage	6.94	6.88	0.33
Lawrence et al. 2013	Grass herbage	6.42	6.57	0.36

Methods:

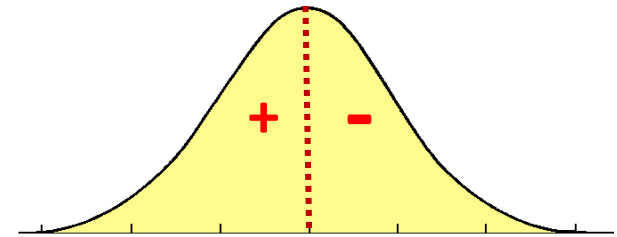
- Esophageal tubing
- Digital pH meter
- Single measurement

P > 0.05

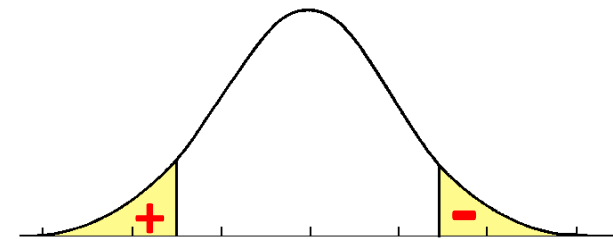
Results and Discussion: microbial ecology

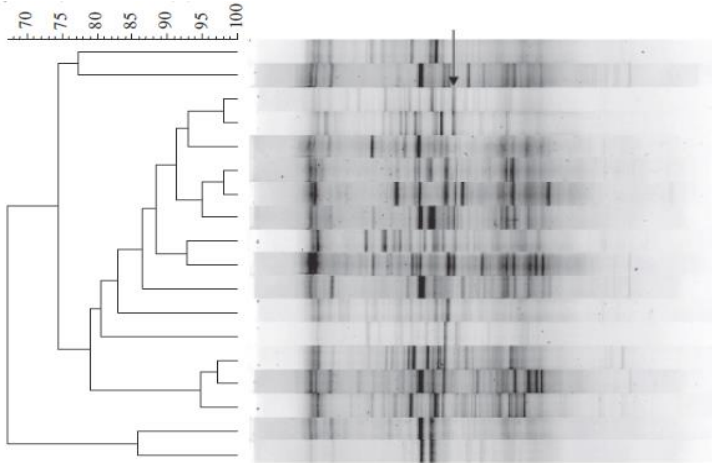


Parameter (copy number/ml)	Efficient	Inefficient	p-value
Bacteria	5.46×10^{26}	5.94×10^{26}	0.92
Protozoa	4.96×10^{16}	2.47×10^{17}	0.37
Methanogen	4.76×10^{21}	1.53×10^{22}	0.17



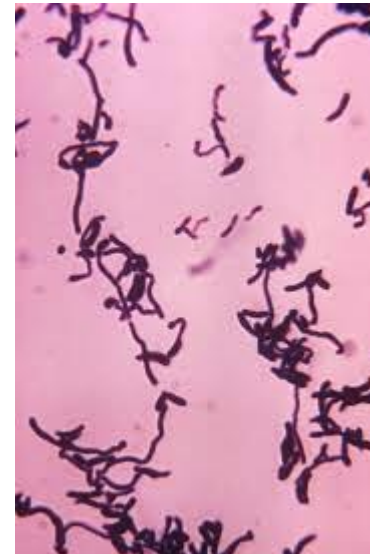
Parameter (copy number/ml)	Efficient	Inefficient	p-value
Bacteria	2.3×10^{27}	8.6×10^{26}	0.33
Protozoa	1.86×10^{16}	3.29×10^{16}	0.83
Methanogen	2.3×10^{21}	1.7×10^{22}	0.13



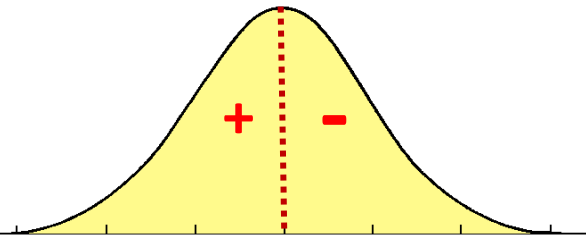


Certain bacterial profiles exist within higher RFI animals (Guan et al. 2008).

Bacterial phylotypes: *Eubacterium* species (Hernandez-Sanabria et al. 2012).

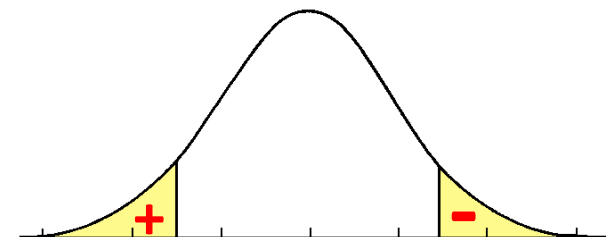


Results and Discussion: volatile fatty acids



Parameter ($\mu\text{mol/ml}$)	Efficient	Inefficient	p-value
Total VFA	83.1	75.2	0.12
Acetic acid	53.7	55.2	0.38
Propionic acid	30.2	28.2	0.36
Butyric acid	8.6	8.9	0.71

Parameter ($\mu\text{mol/ml}$)	Efficient	Inefficient	p-value
Total VFA	87.9	70.1	0.015
Acetic acid	55.1	55.6	0.87
Propionic acid	29.1	29.0	0.97
Butyric acid	8.8	8.2	0.49

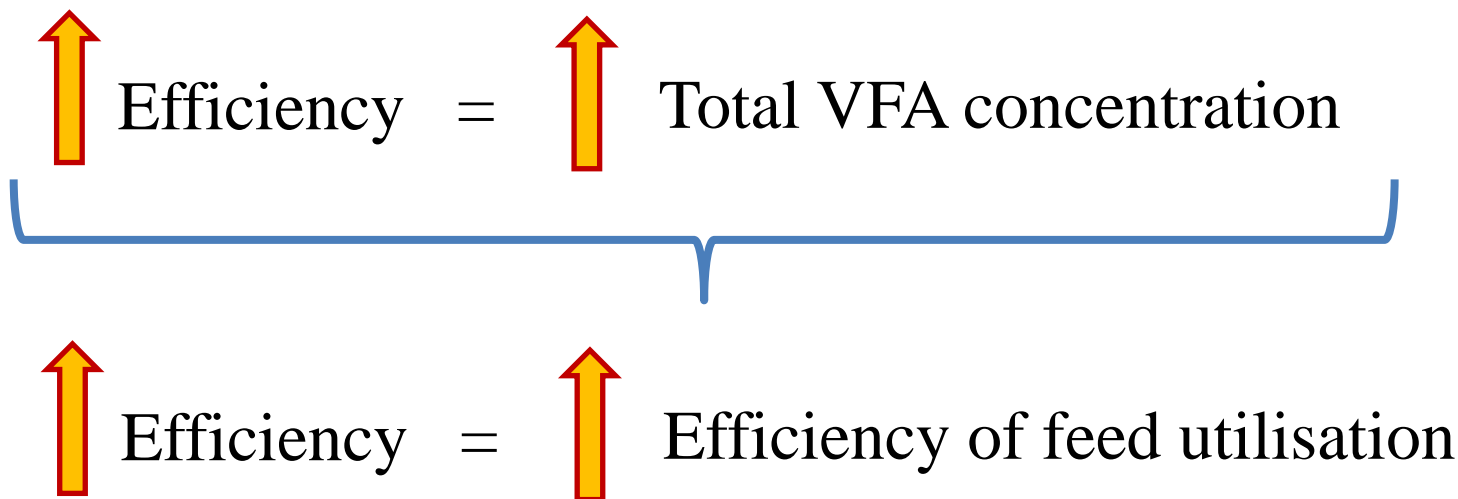


Results and Discussion: **volatile fatty acids**

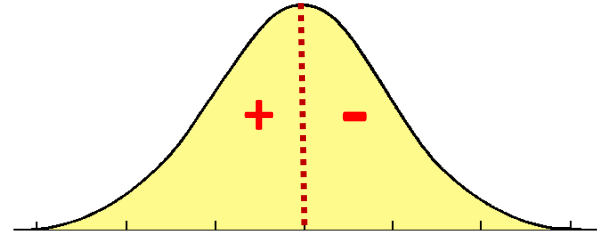


Trait	L-RFI group (efficient)	H-RFI group (inefficient)	P-value
RFI, kg day ⁻¹	- 1.38 ± 0.14	1.40 ± 0.12	< 0.001
Total VFA, mM	96.74 ± 13.07	55.35 ± 13.05	0.059
Acetate, mM	52.67 ± 6.74	31.20 ± 6.73	0.074
Propionate, mM	25.02 ± 5.60	18.04 ± 5.59	0.409
Butyrate, mM	14.54 ± 1.79	3.35 ± 1.79	< 0.001

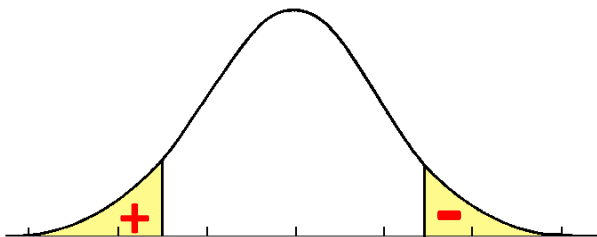
(Guan et al. 2008)



Results and Discussion: epithelium histology

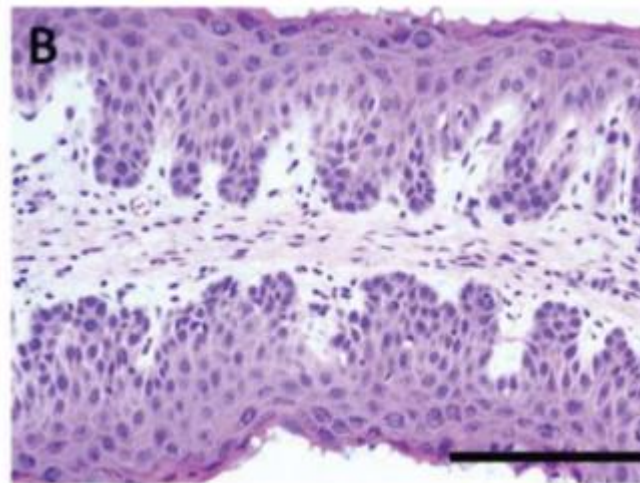
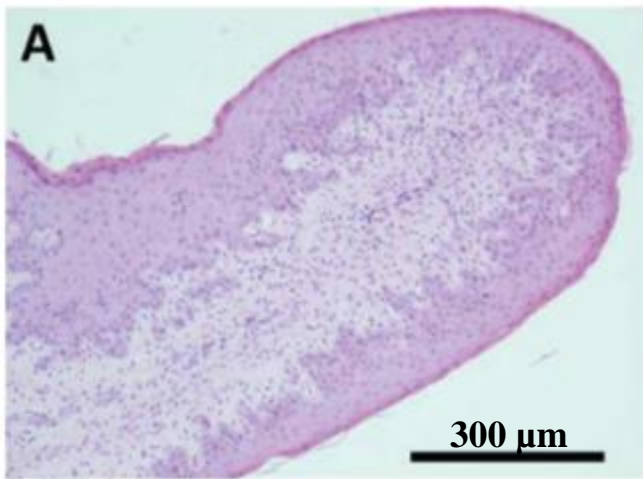


Parameter (μm)	Efficient	Inefficient	P-value
Papillae thickness	120.1	117.9	0.74

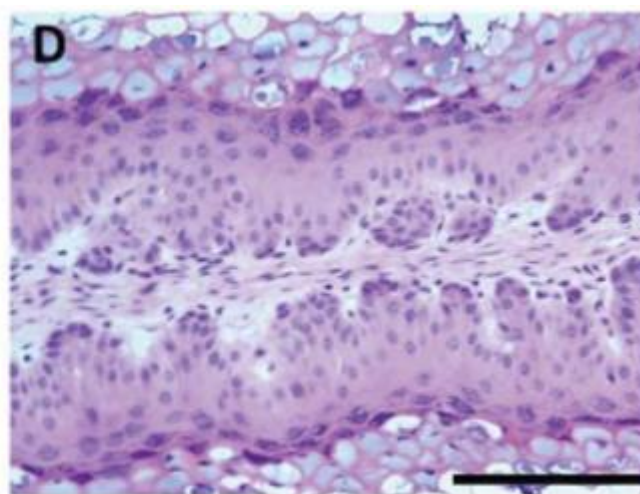
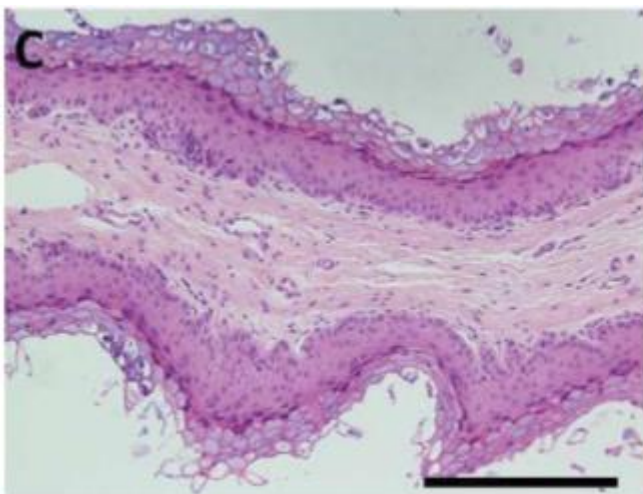


Parameter (μm)	Efficient	Inefficient	P-value
Papillae thickness	120.0	117.9	0.77

Results and Discussion: epithelium histology



Forage diet



High grain diet

High grain diet



Thicker stratum corneum layer

$P < 0.05$

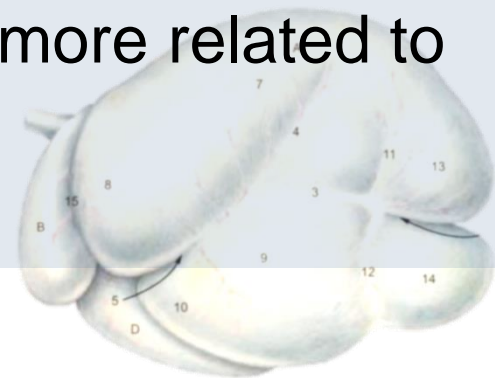
(Steele et al. 2012)

Despite the association between feed efficiency and total VFA concentration.

There is minimal association with ruminal microbiota, pH and temperature, and epithelial structure.



Therefore, variation in feed efficiency may be more related to post-absorptive metabolism.



Acknowledgments



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Elora Beef Cattle Research Center Staff



Stéphanie Bourgon



1. Faculty of Agriculture



2. Western College of
Veterinary Medicine




3.



4.

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

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Foster³,
T. Chenier³, S. Miller^{3,4}, Y. Montanholi¹



66th
EAAP
ANNUAL MEETING



1

Tuesday, Session 25 title (17:30):

Ways of improving udder health and fertility in cattle