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IOWA STATE UNIVERSITY
Department of Animal Science

The physiological basis of differences in efficiency, metabolism and energy partitioning between lines of pigs selected for residual feed intake

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Rationale

- Feed is a major variable cost in pig production.
- Relatively little is known about how metabolism, energy partitioning and mitochondrial function contribute towards feed efficiency in pigs.
- Therefore, it is critical to further define the physiological and molecular mechanisms responsible for improved feed efficiency.
  - This will allow for more effective selection and management strategies to enhance pig production efficiency, profitability and sustainability.

Aims

- Our overall goal is to identify distinguishing metabolic characteristics of finisher pigs selected for low RFI (improved feed efficiency) relative to randomly selected less feed efficient finisher pigs (high RFI). To achieve this goal, we will address three objectives:

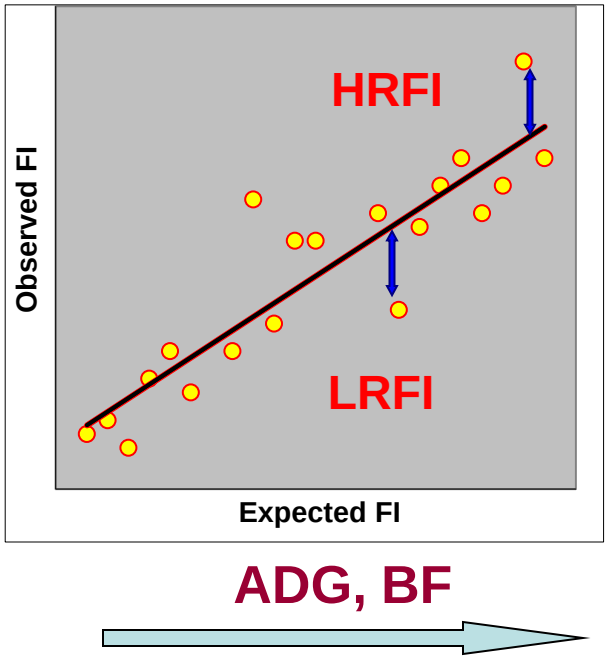
1. Evaluate the extent to which nutrient retention, energy balance and metabolite profile differences contribute to the biological basis for genetic differences in RFI in finisher pigs.

2. Determine the extent to which carcass composition, protein and fat accretion rates explain genetic differences in RFI and improved feed efficiency.

3. Identify key metabolic pathway differences and cellular processors that contribute to altered metabolism, reduced feed intake and enhanced metabolic and feed efficiency in pigs.

Residual Feed Intake (RFI)

$$RFI = FI - \beta_1 ADG - \beta_2 BF$$



- High RFI (HRFI) = reduced FE
- Low RFI (LRFI) = increased FE
- Is a measure of feed efficiency that has improved statistical properties over traditional measures of feed efficiency.
- Refers to the difference between the quantity of feed/energy that a pig is expected to require for maintenance and growth and that actually consumed by the pig.
- Directly focuses on the ability of pigs to use dietary energy most effectively for the metabolic processes of maintenance and growth

ISU Residual Feed Intake Selection Lines

Est. 1999

Low RFI line

Hi RFI line

Experimental Objectives

Develop lines that differ in Residual Feed Intake

Use as a resource population

To understand and develop tools to improve feed efficiency in pigs

Potential factors contributing to RFI

- Body composition
- Physical activity
- Eating behavior
- Maintenance requirements
- Digestibility
- Tissue turnover rates
- Immune response
- Measurement error

Possible physiology that may define the variation in FE, metabolism and RFI

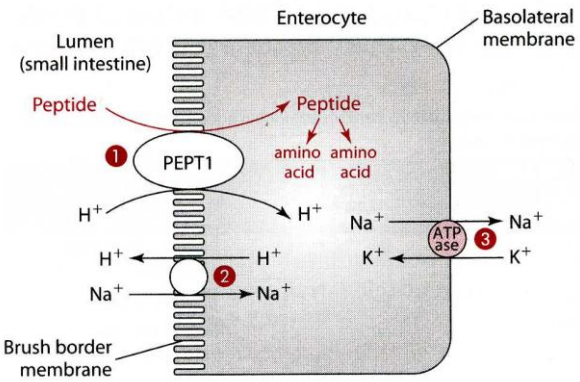
- Ion pumps activity (i.e., Na^+/K^+ ATPase)
- Digestion and nutrient/energy retention
- Body composition and tissue accretion

Ion Pump Activity and Feed Efficiency

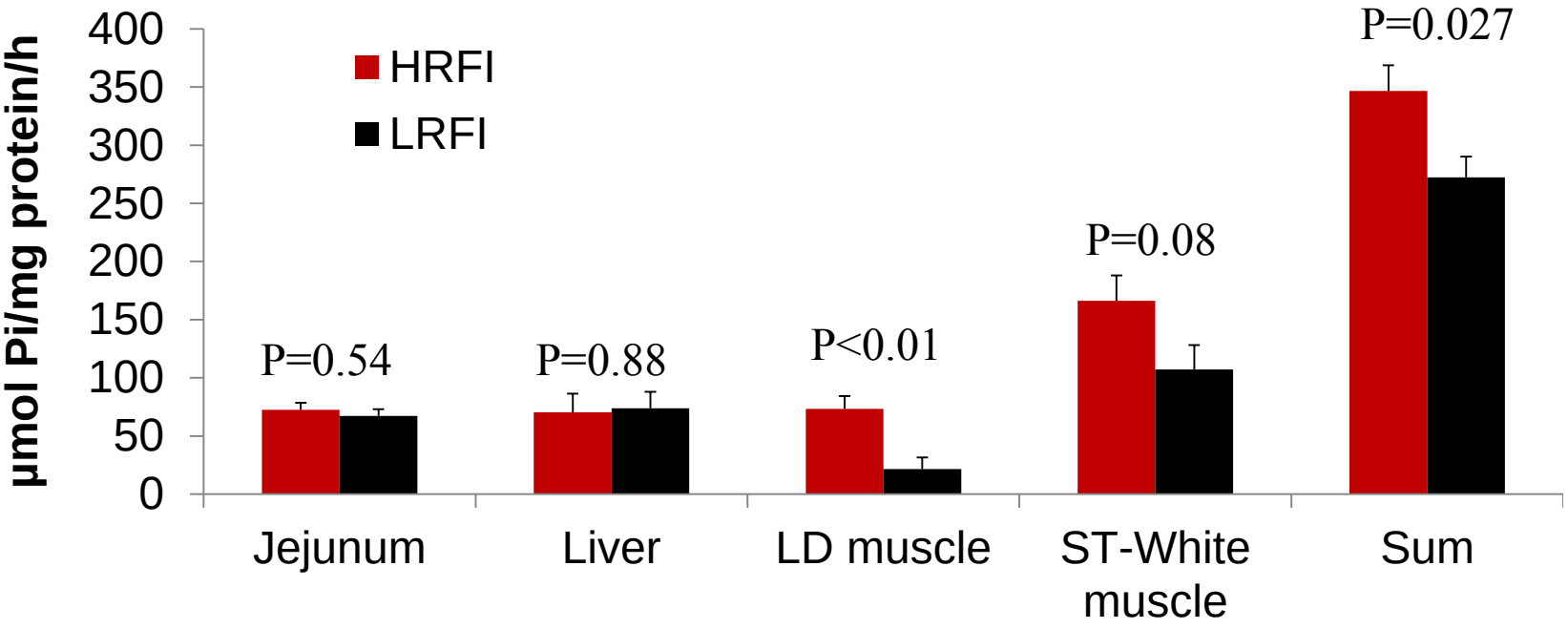
Our *working hypothesis* is that selection for increased feed efficiency have resulted in lower Na^+,K^+-ATPase activity in tissues. This would contribute significantly to improvements in feed efficiency potentially via lowering basal metabolic rates.

Ion Pumps

- Critical for membrane potential and cellular homeostasis
- Energy expenditure on ion transport is significant and varies with the physiological state of the animal
- Of the 80% of oxygen consumption coupled to ATP synthesis (Milligan and McBribe, 1985)
  - H^+ & Na^+,K^+ -ATPase: 19-28%
  - Actinomyosin -ATPase: 2-8%
  - Ca^+ -ATPase: 4-8%



Na^+,K^+-ATPase activity in pigs divergently selected on RFI



- Tissue specific differences in Na^+,K^+-ATPase activities
- LRFI pigs had lower muscle and total activity

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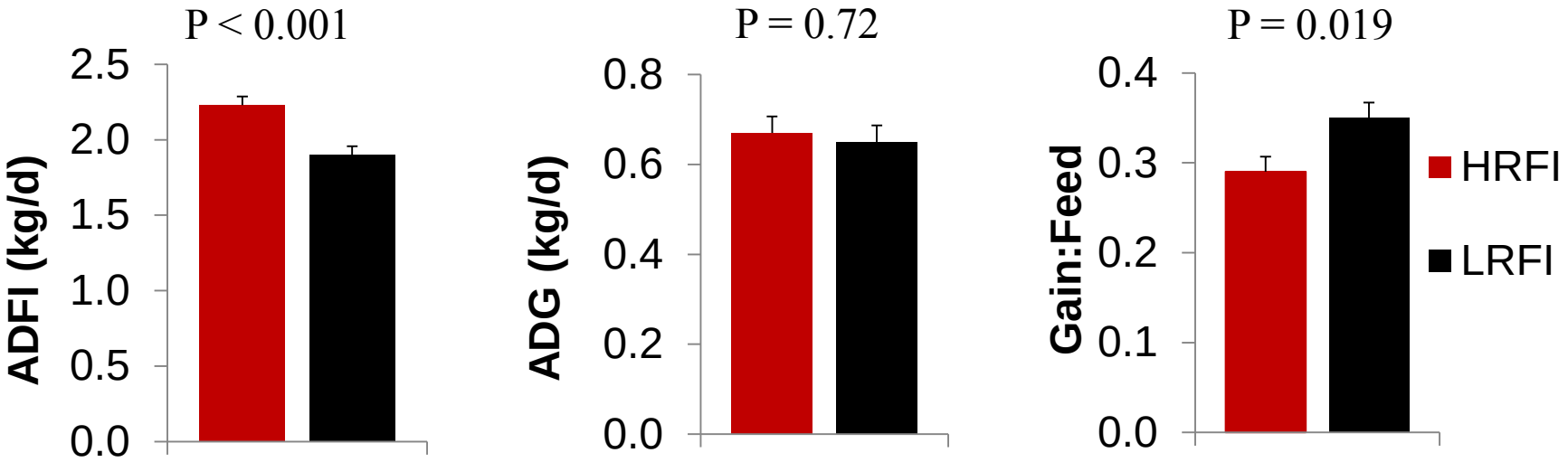
Nutrient and Energy Digestibility and Retention

Our *working hypothesis* is that finisher pigs selected for LRFI have increased nutrient digestibility and retention, in particular nitrogen, and altered blood and urine metabolite profiles reflecting differences in metabolism relative to pigs from the less efficient HRFI line.

Amanda Harris – MS student

RFI gilt performance



- Data based on a 5 week individual growth performance study
- Gilts started at 67 kg BW
- n = 12 pigs/line

Selection for RFI improves total tract nutrient and energy digestibility

	LRFI[1]	HRFI[1]	P-value
Digestibility coefficient, %			
Dry Matter	87.3 ± 0.25	85.9 ± 0.25	0.0006
Nitrogen	88.3 ± 0.47	86.1 ± 0.47	0.003
Phosphorus	65.0 ± 1.10	62.4 ± 1.10	0.12
Gross Energy	86.9 ± 0.25	85.4 ± 0.25	0.0006
EE/fat	64.7 ± 0.57	64.2 ± 0.57	0.56
Ash	65.7 ± 0.53	67.1 ± 0.53	0.08
Energy values, MJ/kg of DM			
DE	16.6 ± 0.05	16.3 ± 0.05	0.0006
ME[2]	16.0 ± 0.05	15.7 ± 0.05	0.0006

[1] n=12 gilts per line

[2] ME= DE * [1.003-(0.0021*CP% in diet)]

Selection for RFI tended to increase nitrogen balance in finisher gilts

	LRFI[1]	HRFI[1]	P-value
N balance[2], g/d			
Absorbed	55.4 ± 0.41	54.3 ± 0.41	0.12
Retained	36.9 ± 1.53	32.1 ± 1.53	0.08
P balance[2], g/d			
Absorbed	10.7 ± 0.29	10.4 ± 0.29	0.49
Retained	9.4 ± 0.24	8.9 ± 0.24	0.21

[1] n=12 gilts per line
[2] Adjusted for ADFI

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RFI Body Composition and Tissue Accretion

Our *working hypothesis*, is that pigs selected for LRFI will have higher lean accretion and lower fat deposition compared to the less efficient HRFI line pigs.

Amanda Harris – MS student

Body Composition

- The deposition of the same weight of lean and fat tissue has different energy costs
  - More variation in lean deposition
  - Lean tissue has a higher turnover rate than fat → energetically expensive process
  - Decreased rates of protein degradation give rise to improved conversion of feed to gain in many species

    (Herd and Arthur 2009)

  - Of the 80% of oxygen consumption coupled to ATP synthesis
    - Protein synthesis: 25-30%
    - Ureagenesis: 3%

Growth performance of body composition and tissue accretion gilts – Serial slaughter study

Parameter	LRFI[1]	HRFI[1]	SE	p-value
Live weight (kg)	90.5	89.8	3.23	0.88
HCW (kg)	72.4	71.3	0.72	0.32
ADFI (kg/d)	2.11	2.43	0.100	0.03
ADG (kg/d)	0.69	0.68	0.022	0.92
G:F	0.33	0.28	0.013	0.01
Backfat (mm)	13.61	16.50	0.520	0.0007
Loin Eye Area (cm^2)	40.83	36.87	1.316	0.04

[1]n=12 gilts per line

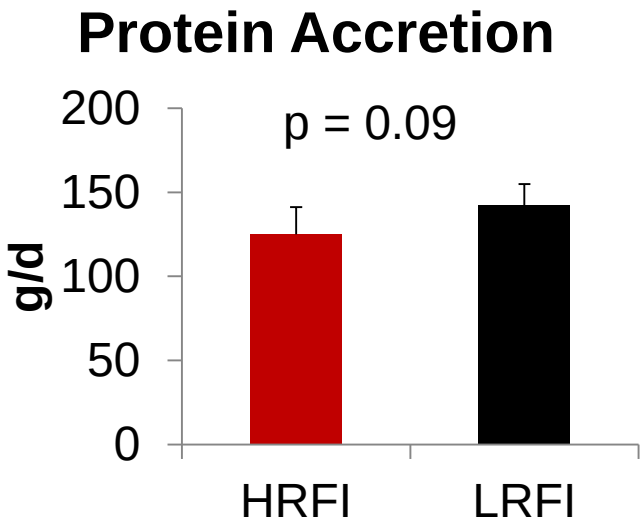
Whole body composition for final slaughter group – Serial slaughter study

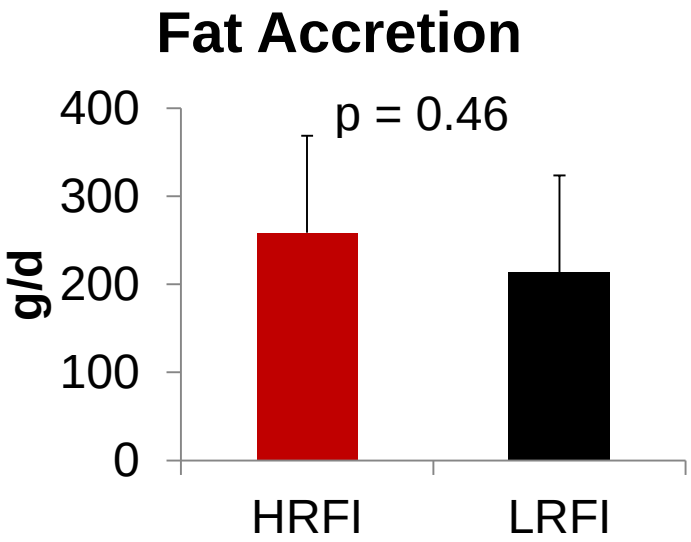
Body Composition (%)	LRFI[1]	HRFI[1]	SE	p-value
Water	61.39	58.24	0.660	0.003
Crude Protein	18.38	17.47	0.282	0.032
Lean	79.78	75.71	0.868	0.003
Fat	17.20	20.68	0.955	0.018
Ash	3.36	3.01	0.097	0.019
Gross Energy, cal/g	6646	7072	74.7	0.0006

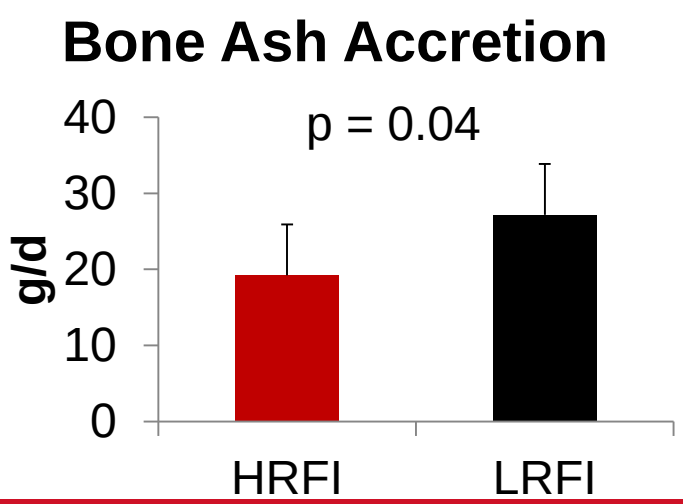
[1]n=12 gilts/line

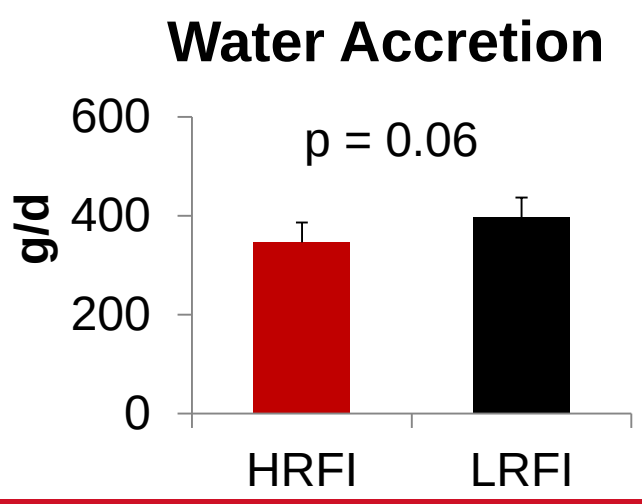
- Blood and total viscera weights tended to be heavier in the HRFI
- HRFI pigs tended to have a larger Viscera:BW ratio

Tissue Accretion – Serial slaughter study









Summary/Impact

- Results form our RFI selection line project indicate that there are multiple systems and pathways underlying feed efficiency

- These data partially agree with other similar selection projects

- Key areas of opportunity to enhance FE in pigs
  - Digestion and nutrient/energy retention
  - Tissue accretion and protein turnover

  - Oxidative stress
  - Lowering maintenance requirements
  - Appetite regulation and feed frequency as it relates body composition/metabolism

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