Improvement of feed efficiency: lessons from residual feed intake studies in pigs - part 1

Hélène GILBERT - Jack DEKKERS

OUTLINE

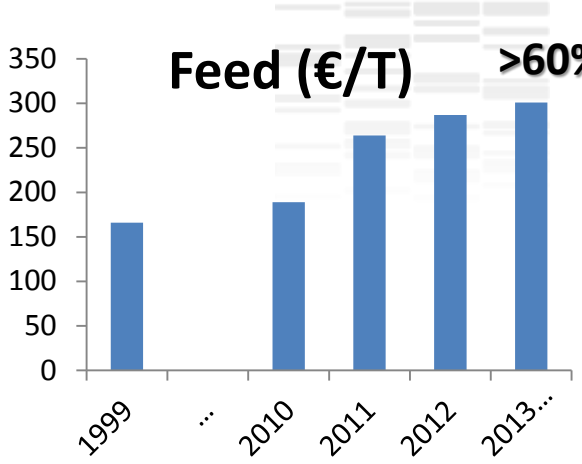
Part1

- From feed efficiency to residual feed intake (RFI)
- Properties and measures of RFI
- Selection experiments for RFI
- Genetic parameters and correlated responses to selection
- Biological bases of RFI

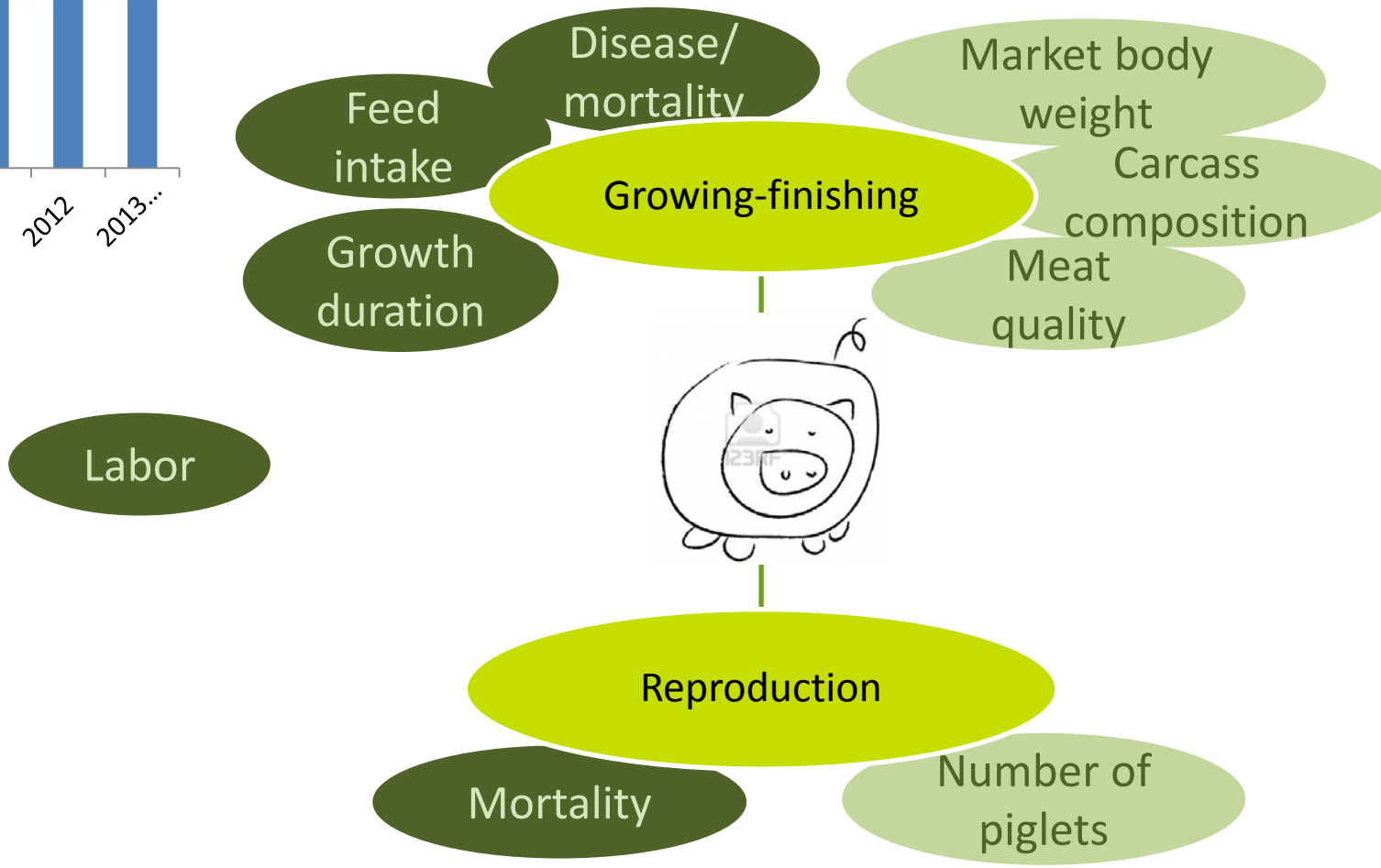
Part2

- Measuring (residual) feed intake / bio-markers for RFI
- Management rules and RFI
- What selection strategies ?

Costs of production / Gains



>60% production costs



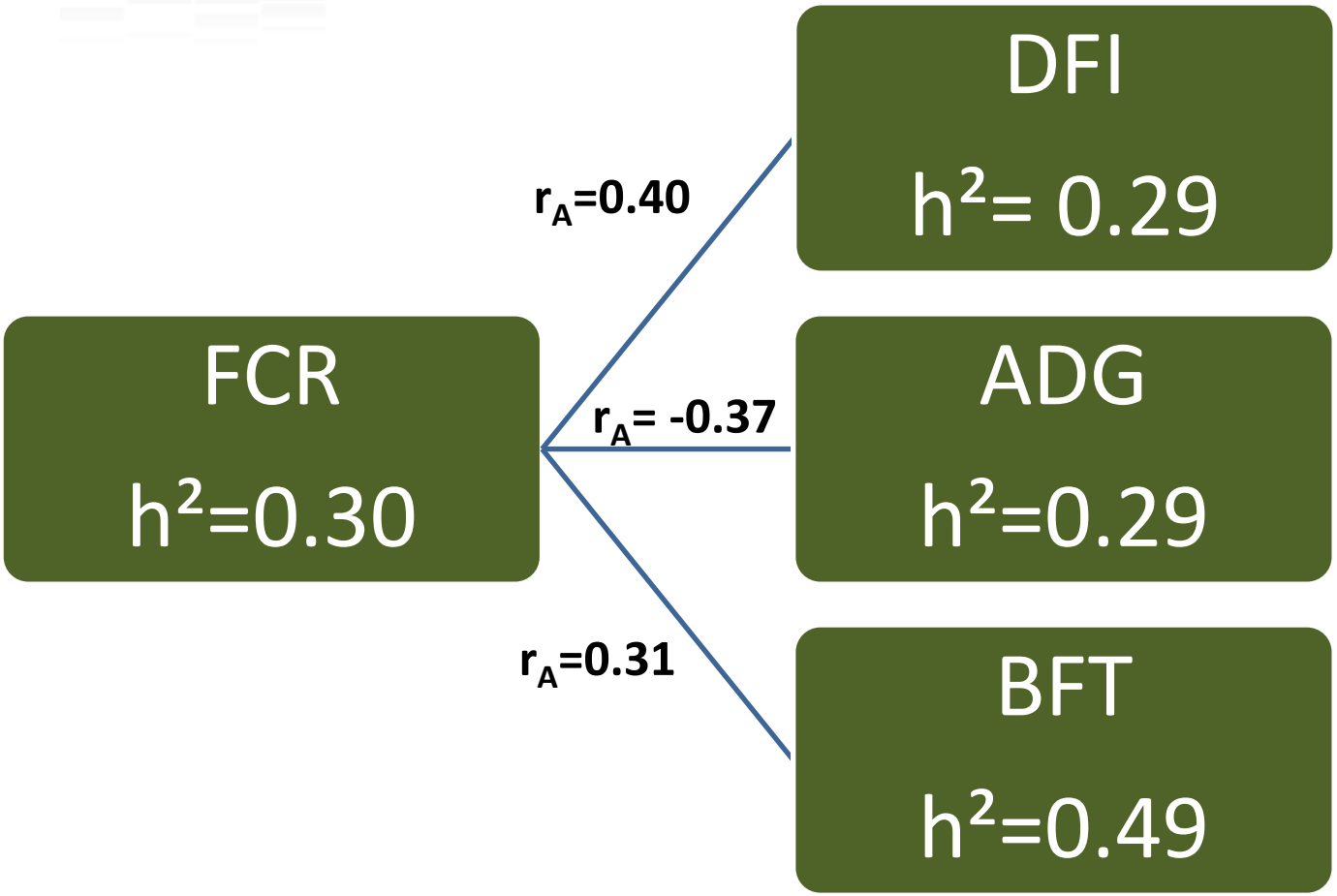
Feed efficiency

$$\text{Feed efficiency} = \frac{\text{weight gain}}{\text{feed intake}} = \frac{\text{average daily gain}}{\text{daily feed intake}}$$

Not included : payment for carcass composition
pig level: mortality

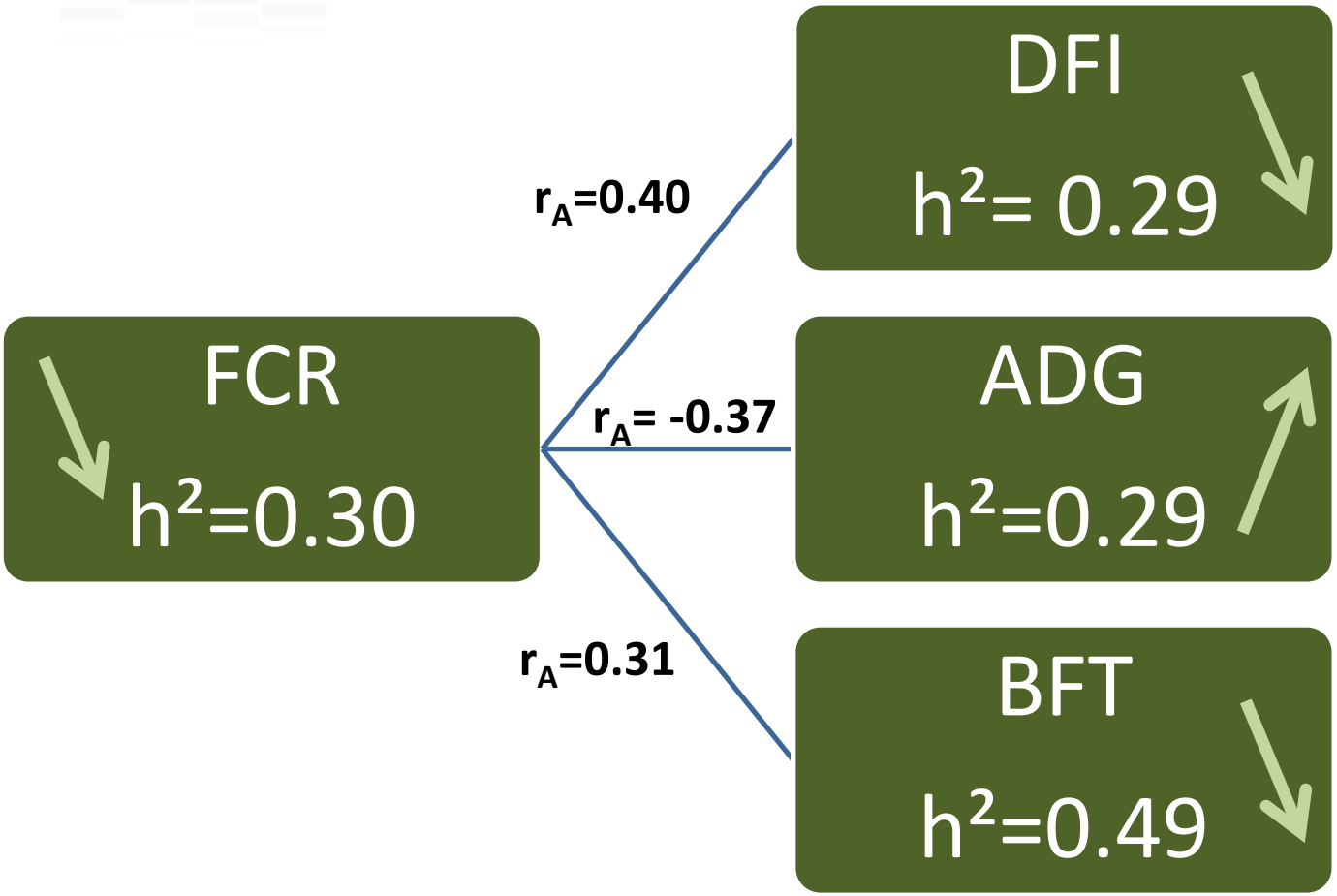
$$\text{Feed Conversion Ratio} = \frac{\text{DFI}}{\text{ADG}}$$

Correlations with production traits



From Clutter et al, 2011

Indirect selection vs DFI records



From Clutter et al, 2011

Components of Feed Intake

$$FCR = \frac{DFI}{ADG}$$

Components of Feed Intake

Body gain Gain composition Time	metabolic body weight	?
production requirements	maintenance requirements	residual

$$FCR = \frac{DFI}{ADG}$$

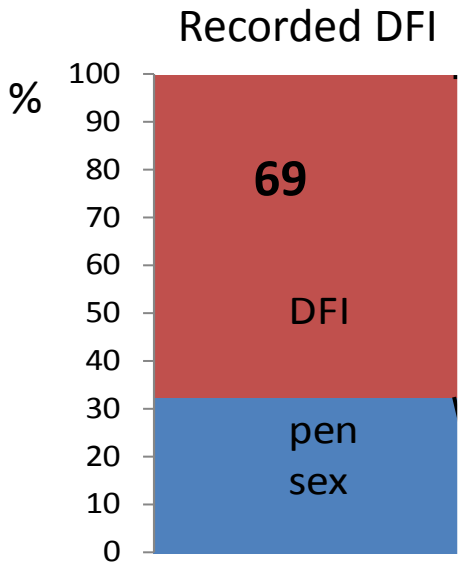
Components of Feed Intake

Body gain Gain composition Time	metabolic body weight	Net feed efficiency ?
production requirements	maintenance requirements	residual

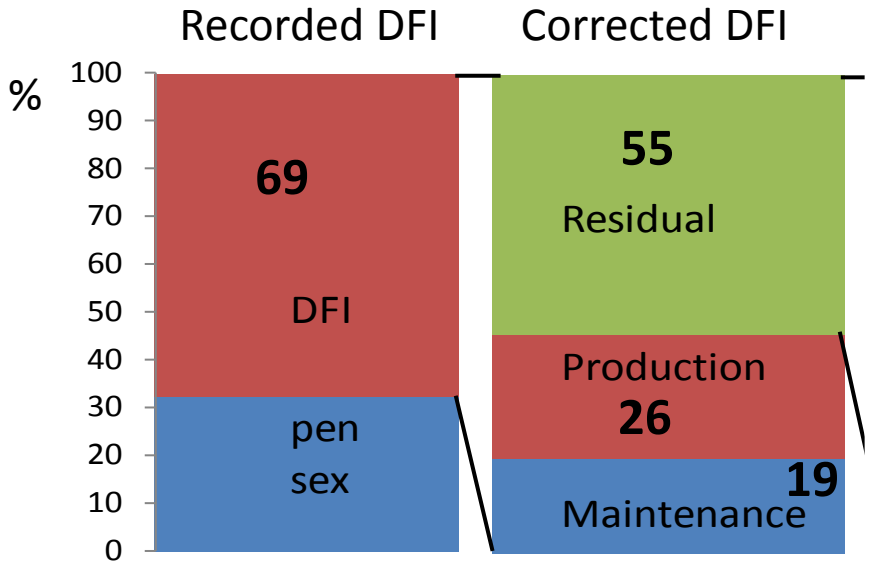
Gross feed efficiency

$$FCR = \frac{DFI}{ADG}$$

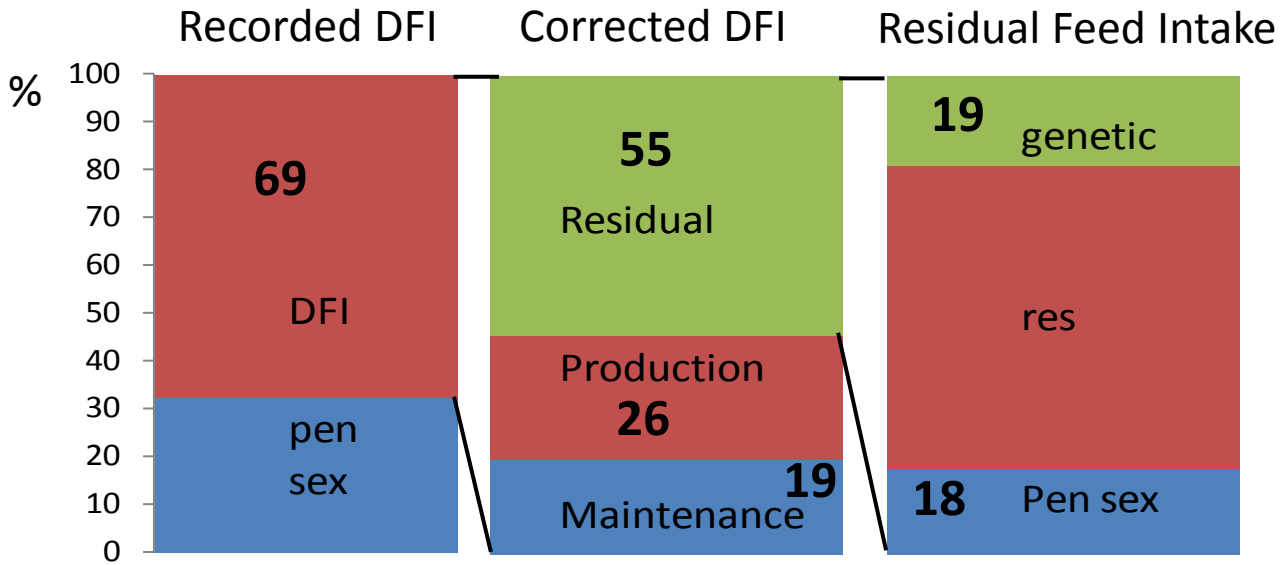
Components of Feed Intake



Components of Feed Intake



Components of Feed Intake



RFI = 20 to 35% of DFI variability

Residual Feed Intake / phenotypic regression

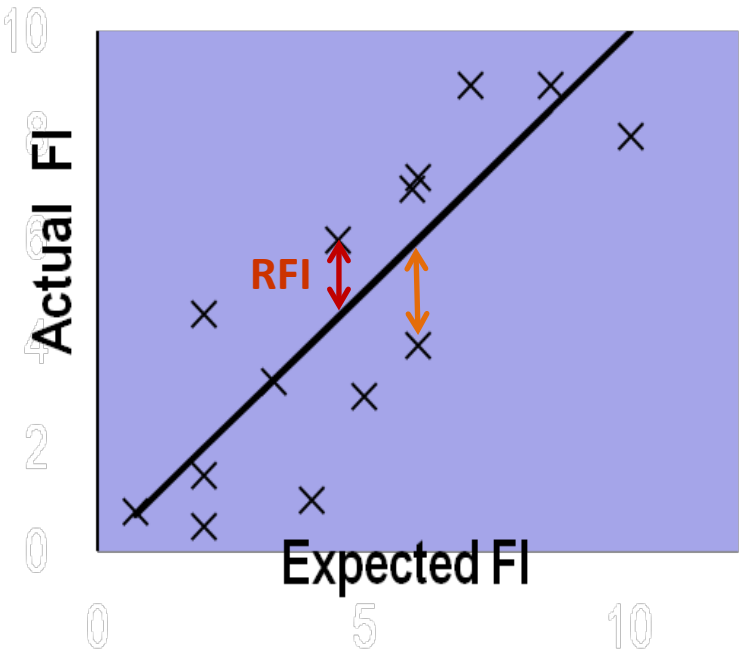
RFI = DFI

– a . maintenance

– b . production

– pen…

Include measurement errors



Koch et al. (1963)

What traits to include?

RFI = DFI

– a . **maintenance** – b . **production** –…

Metabolic Body Weight

Growth rate ADG

Composition tissue deposition

Ultrasonic BFT

Lean meat content

Loin Eye Area …

Kennedy et al. (1993)

When body composition included

0.22 (22 estimates in the litterature)

≠ Net FE

When body composition is not included

0.36 (8 estimates in the litterature)

Saintilan et al (2012)

Correlations with components ?

Phenotypically

Expected to be null

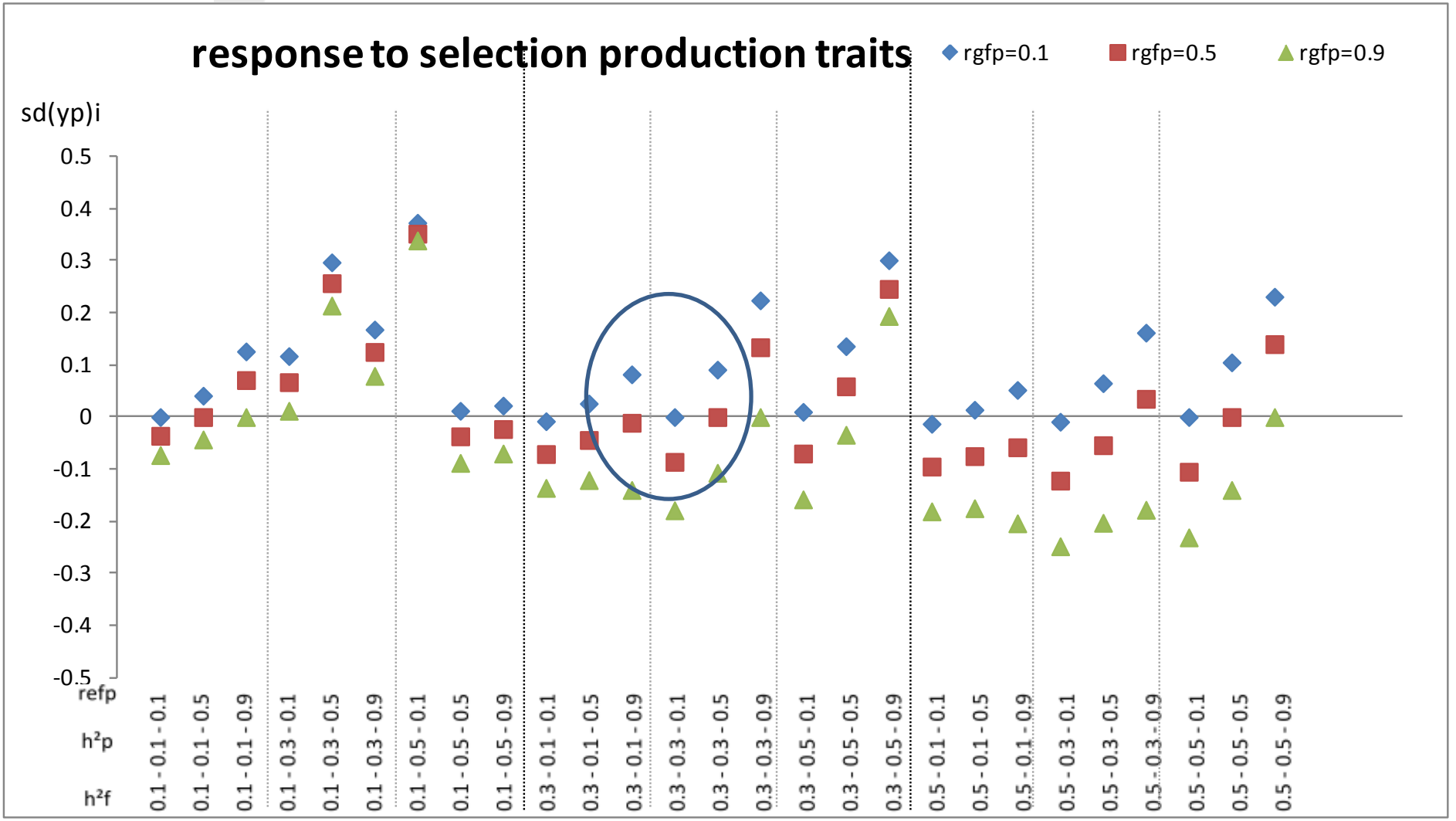
Genetically

depends on h^2, r_A, and r_e

between DFI and component traits

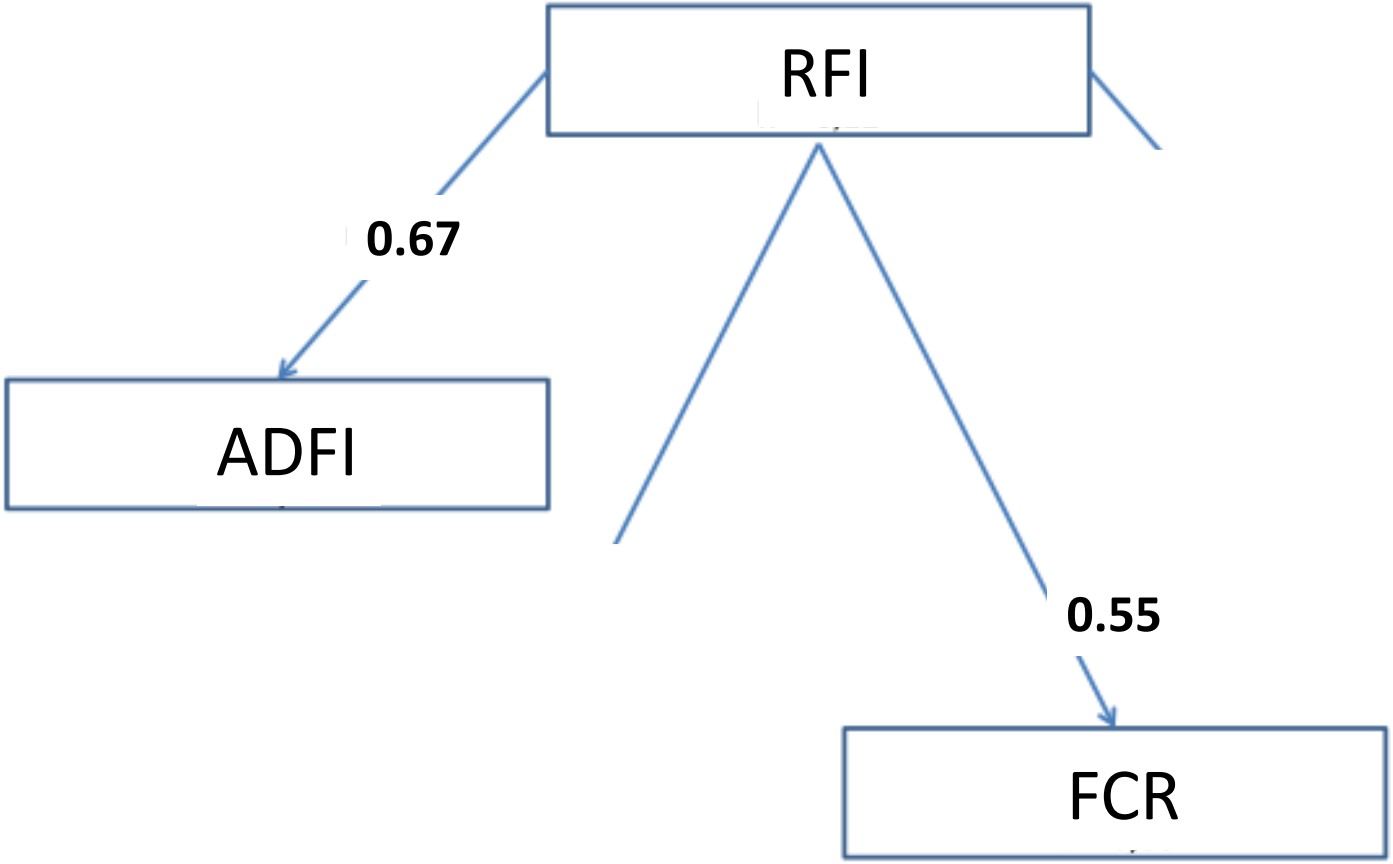
Kennedy et al. (1993)

Correlations with components ?



Kennedy et al. (1993)

Genetic correlations with prod.



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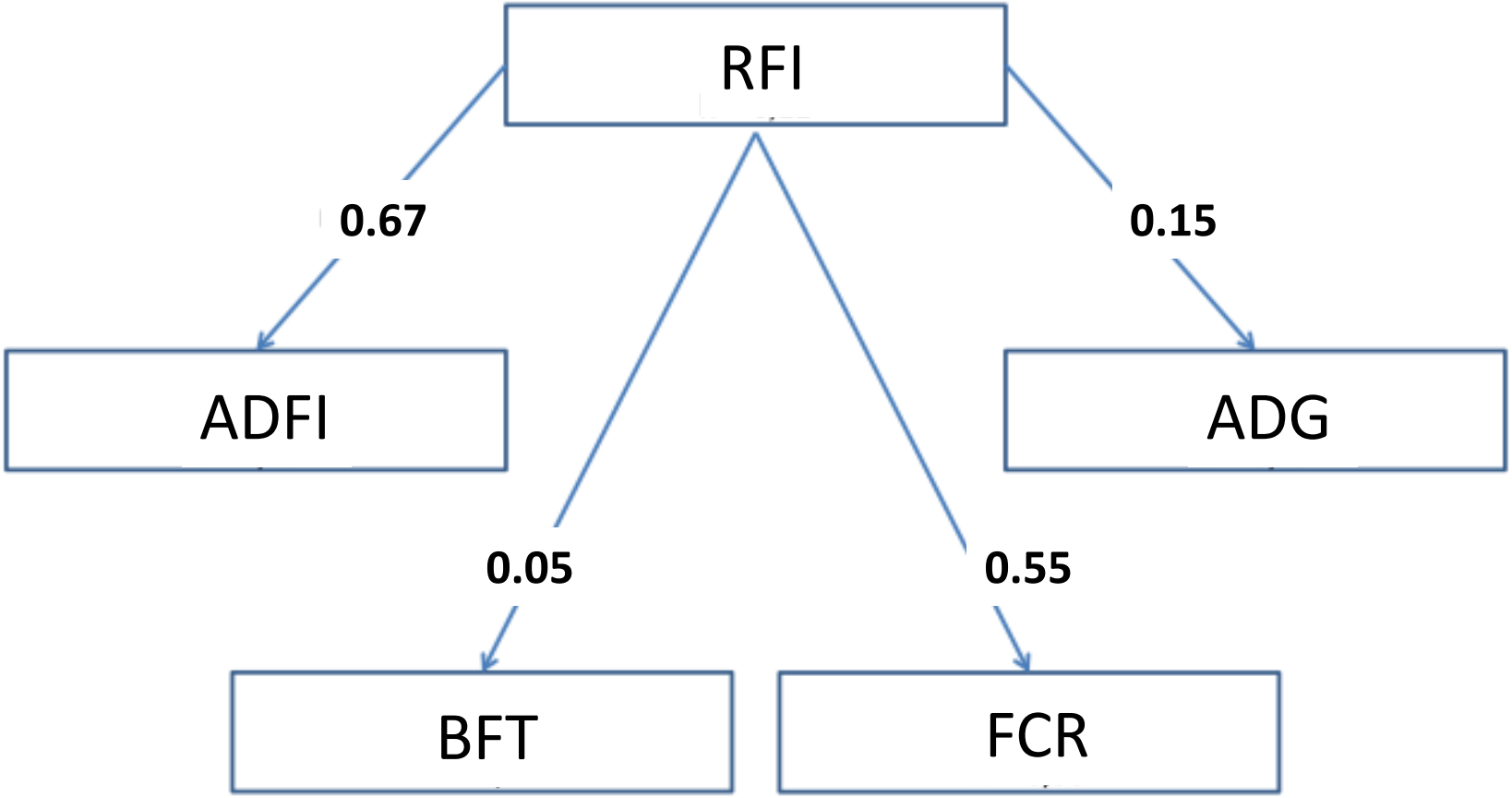
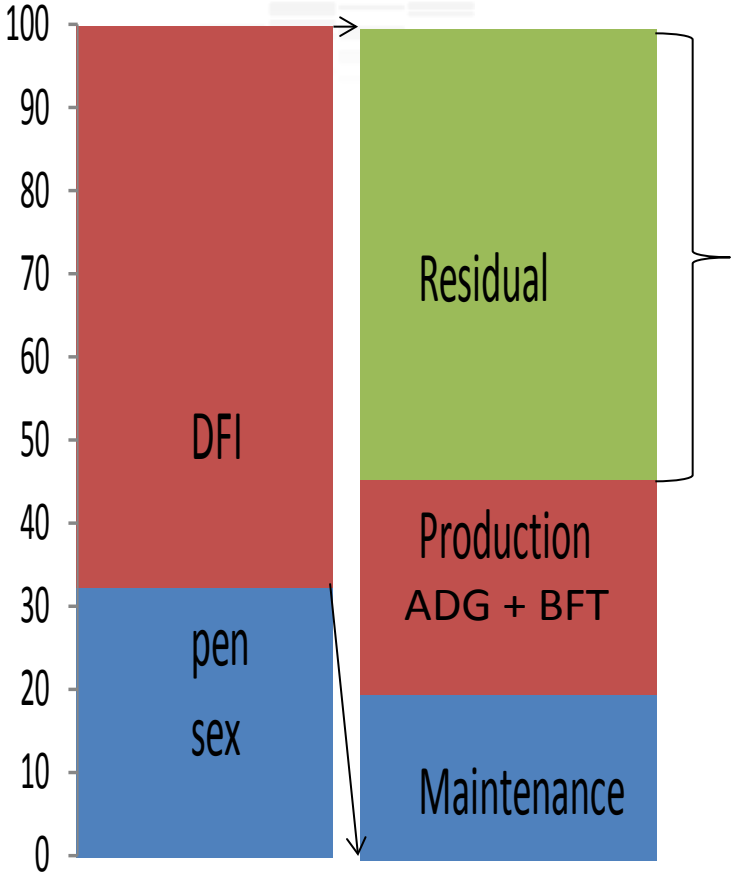
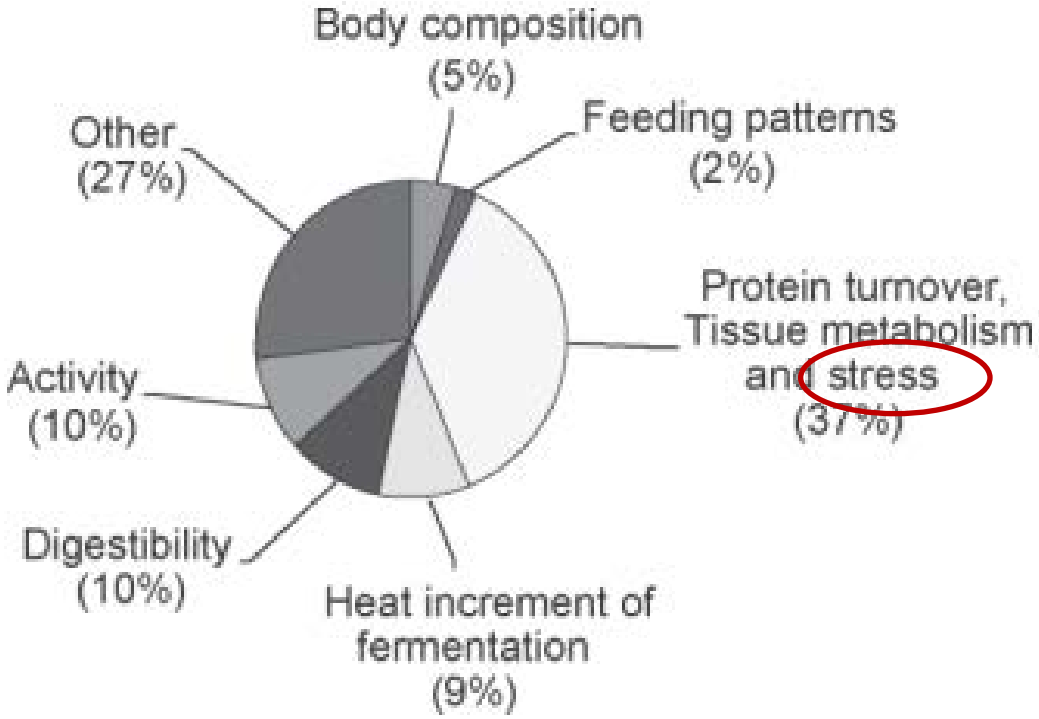


From Clutter et al (2011)

What's in RFI?





(Cattle) Richardson and Herd 2004

Selection experiments

Yorkshire - Large White

Low RFI line

High RFI line

Develop divergent lines for RFI

to study

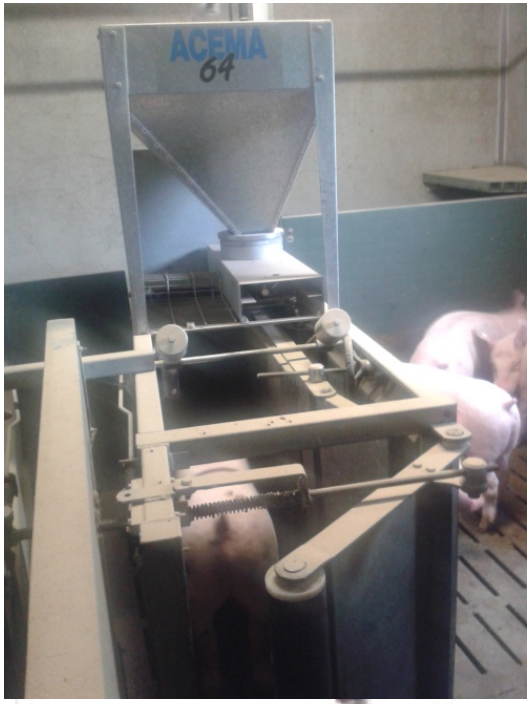
the **responses to selection** for RFI

the **biological basis**

of ingestion and feed efficiency

Measure of feed intake

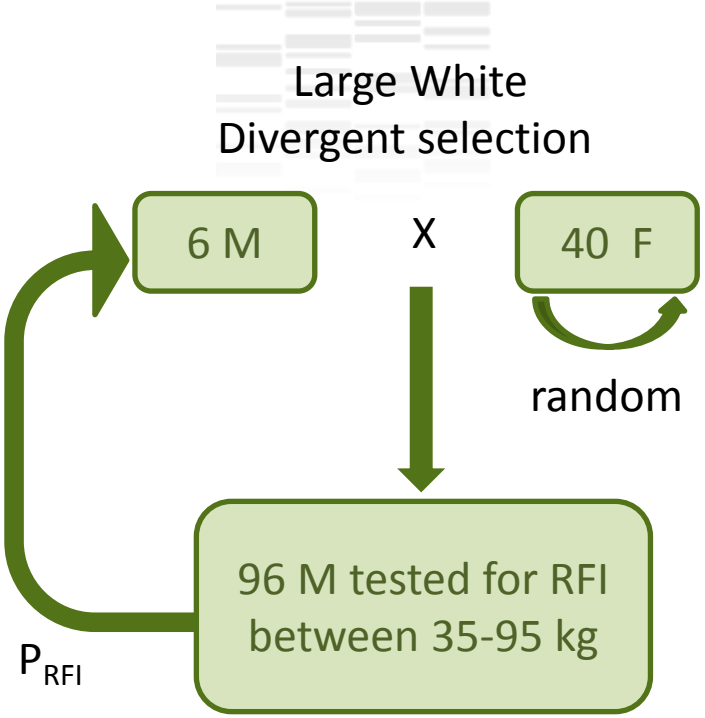
ACEMA 64

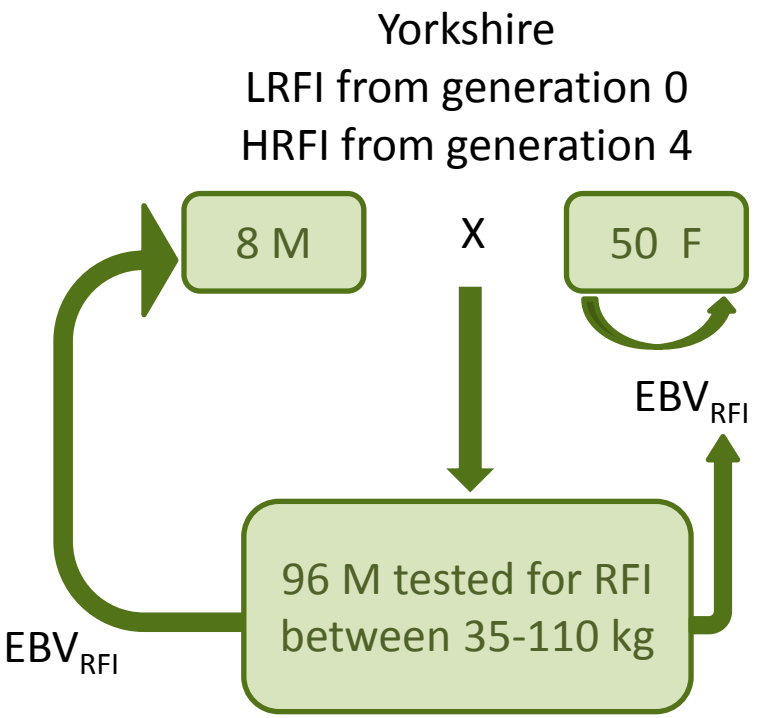


FIRE©

+ electronic identification

Selection procedure





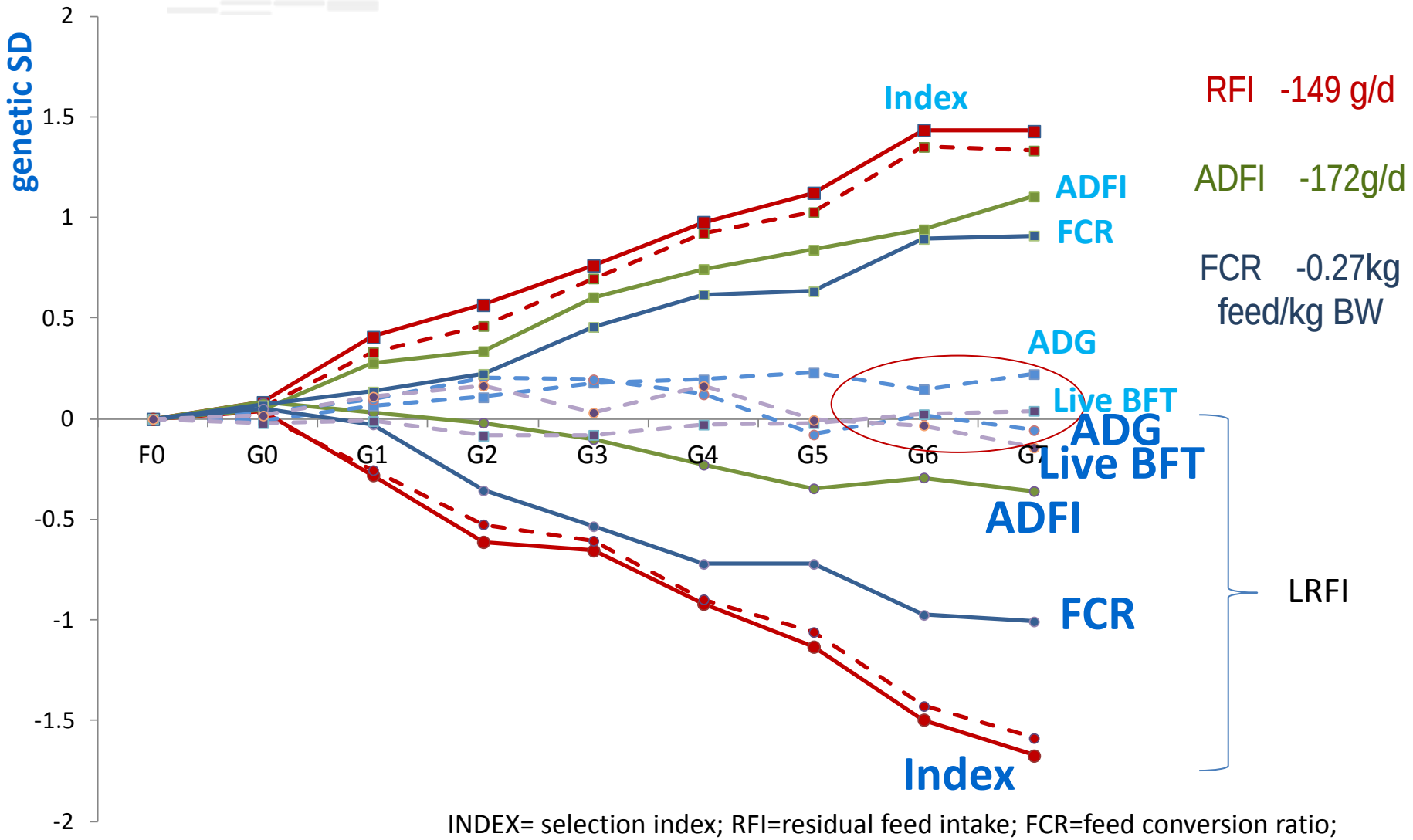
$$\mathbf{Index_{RFI}} = DFI - 1.6\ AGD - 37\ BFT$$

between fixed body weights

$$DFI = b_1 BW_{ontest} + b_2 age_{ontest} + b_3 BW_{offtest} + b_4 ADG_{gen} + b_5 BF_{gen} + \mathbf{BV_{RFI}} + e$$

(Correlated) responses to selection

Responses to selection



INDEX= selection index; RFI=residual feed intake; FCR=feed conversion ratio; DFI=daily feed intake; ADG= average daily gain; BFT= backfat thickness

(Correlated) responses to selection

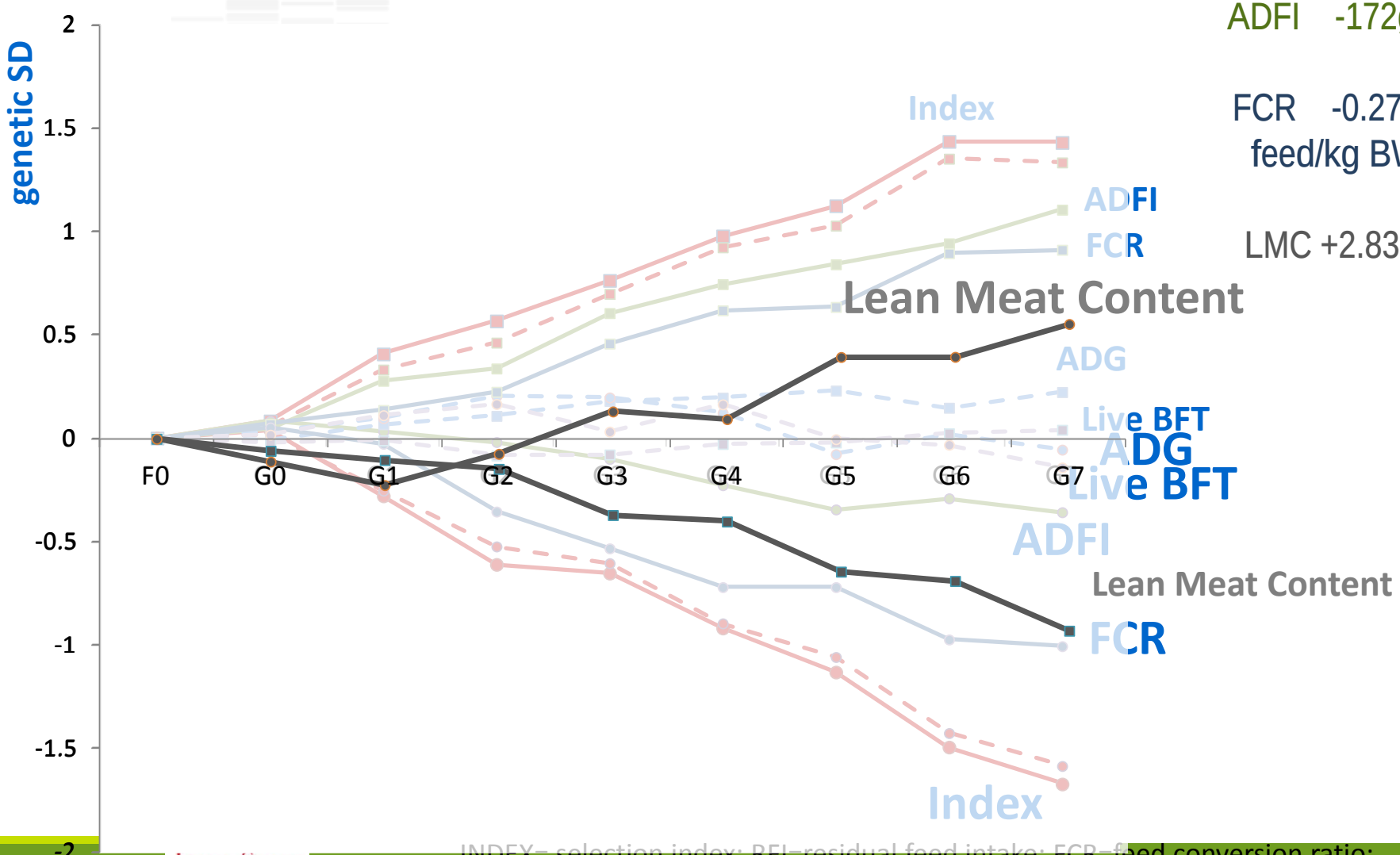
Responses to selection

RFI -149 g/d

ADFI -172g/d

FCR -0.27kg feed/kg BW

LMC +2.83%



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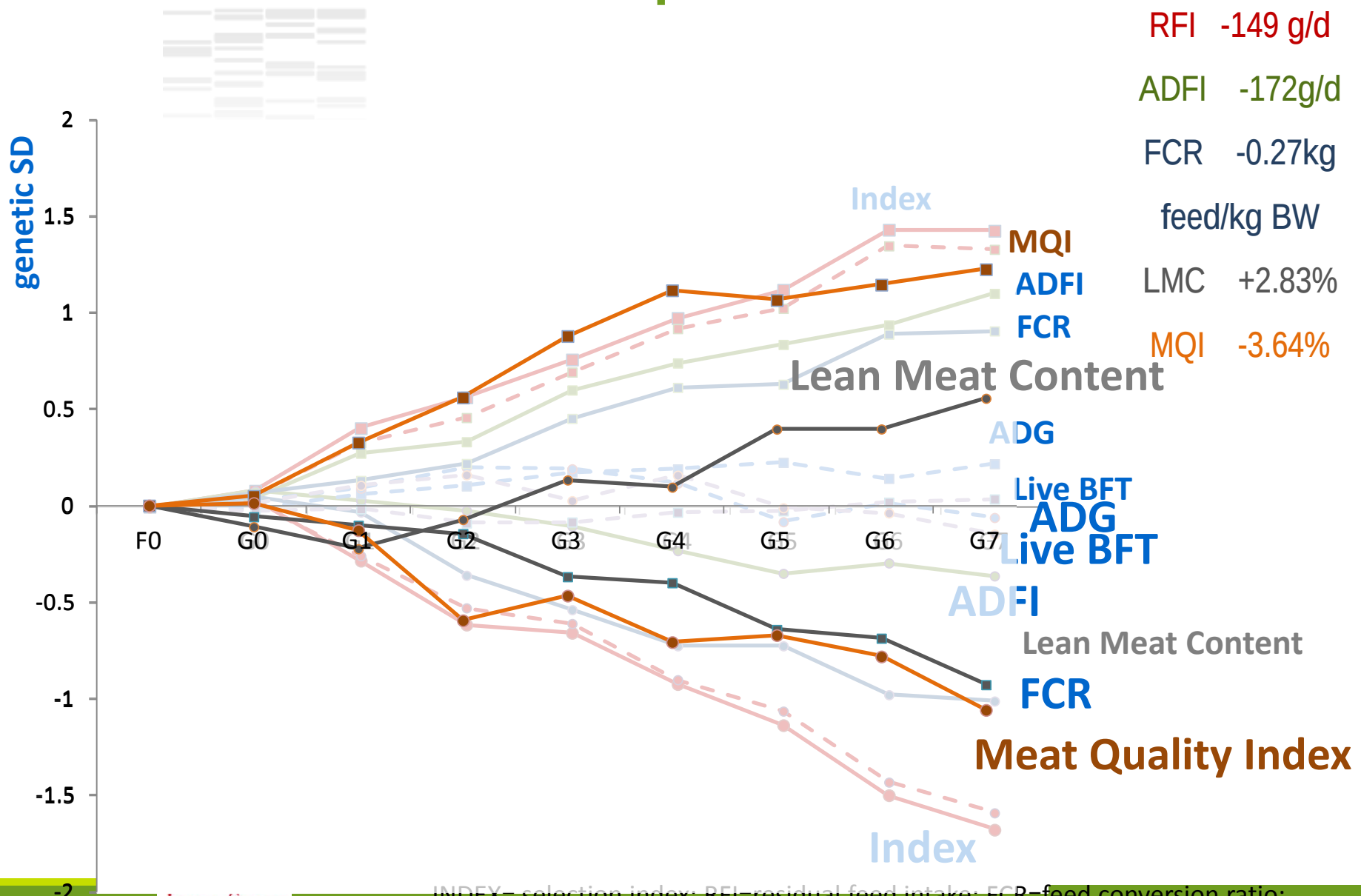
Responses to selection



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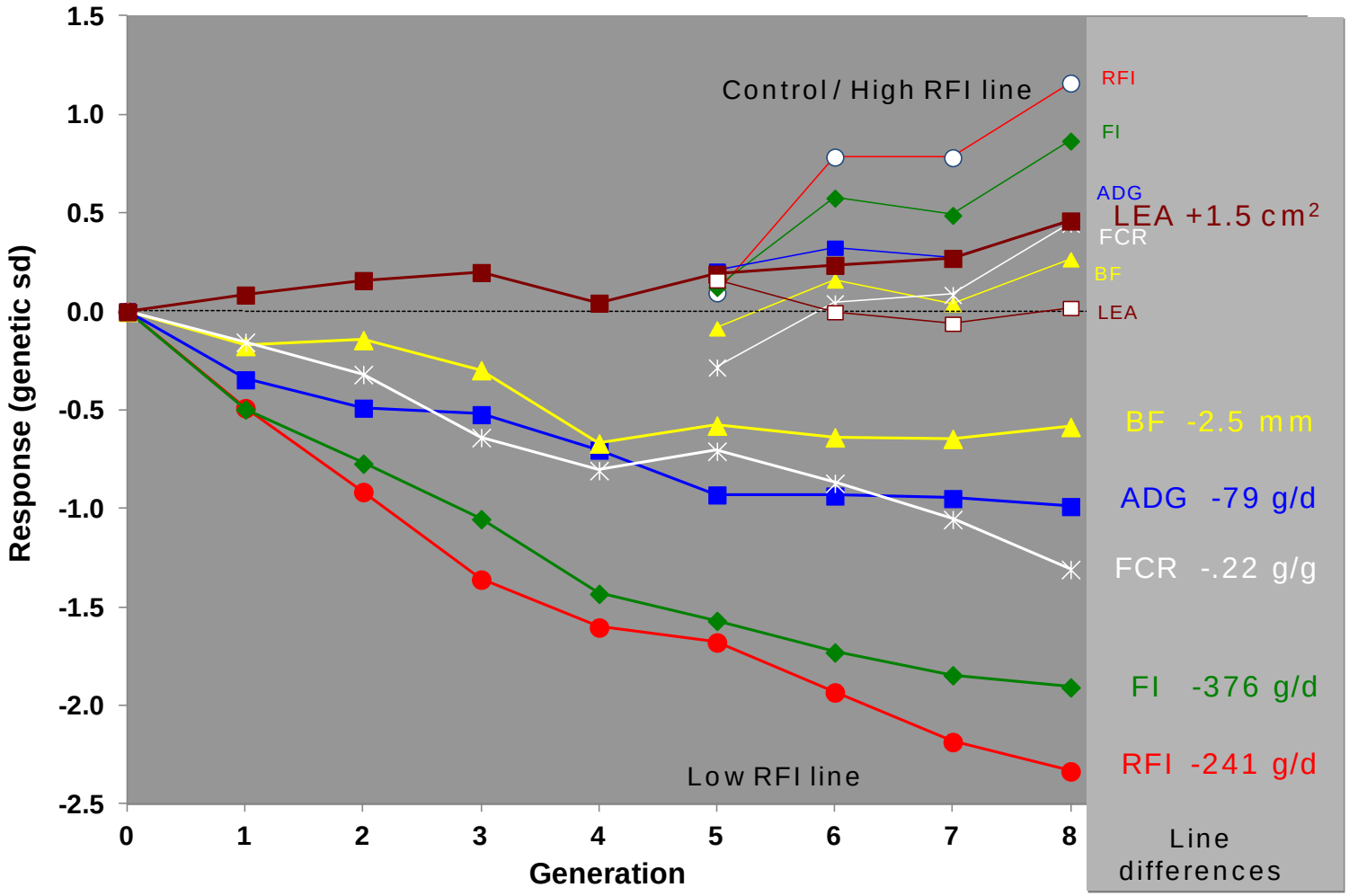
Responses to selection



➔ Body composition = up to 87% of line difference for net energy feed intake

Meat quality

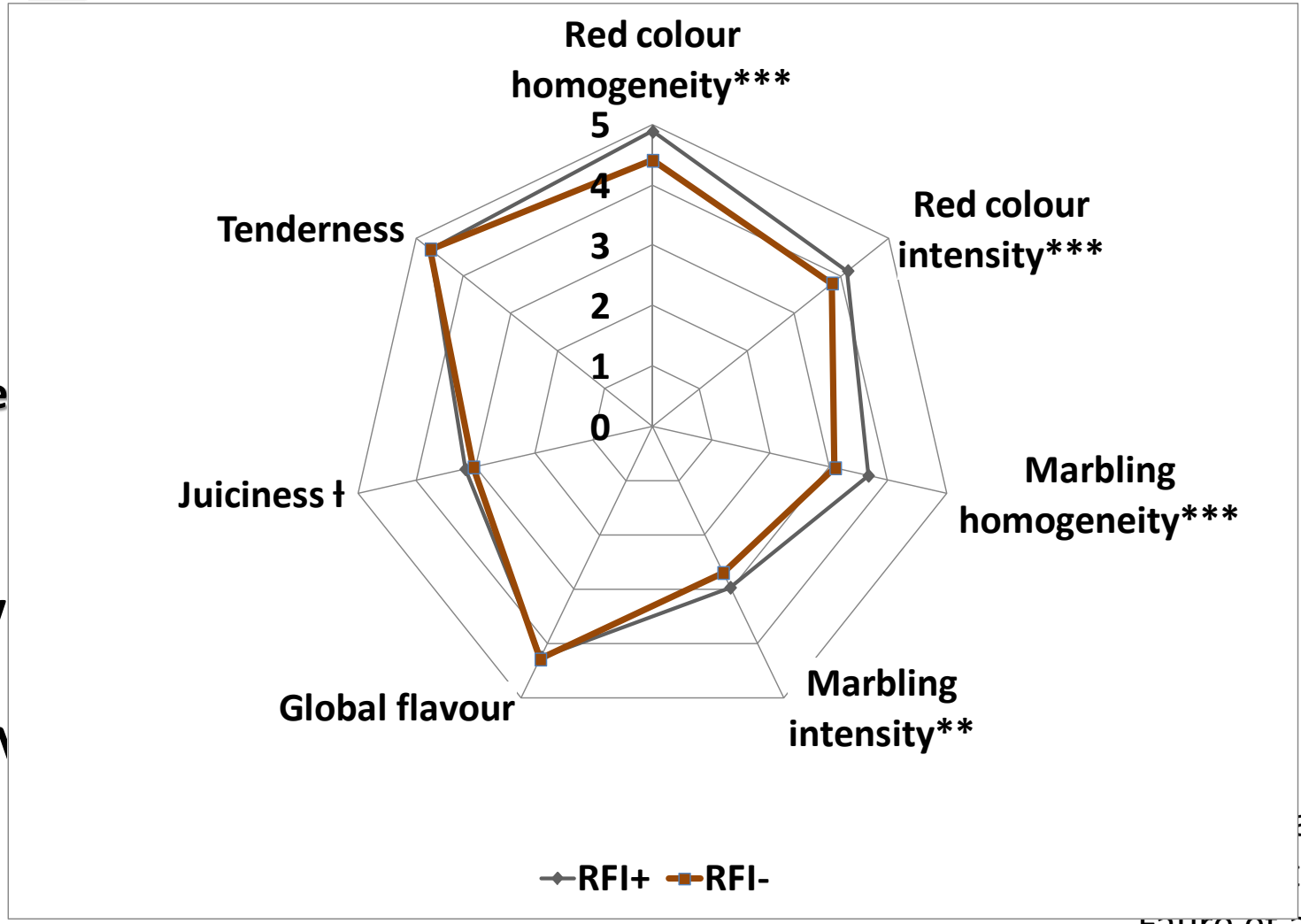
Some indicators of unfavorable impact of selection for RFI on meat quality

in INRA lines
Very large early correlated response

Low in ISU lines

Smith et al, 2010
Gilbert et al, 2007
Faure et al, 2012

(Correlated) responses to selection Meat quality



Ve

Equiv

FCR

N

al, 2010

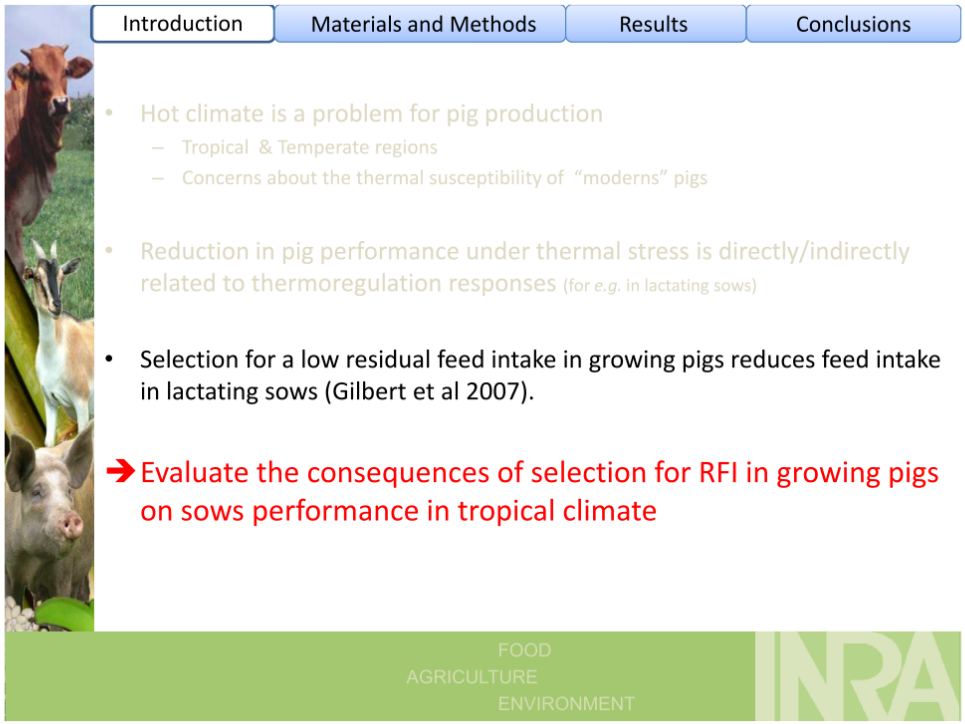
al, 2007

Faure et al, 2012

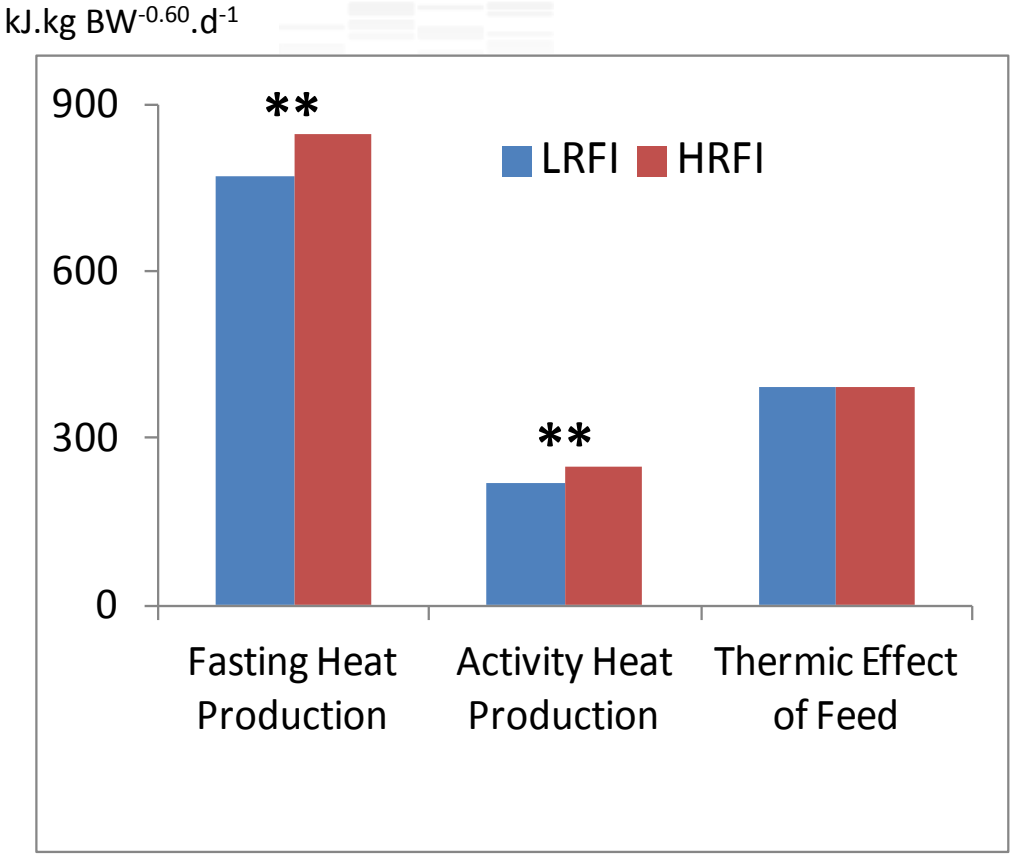
Gilbert et al, 2012
Young et al, 2010

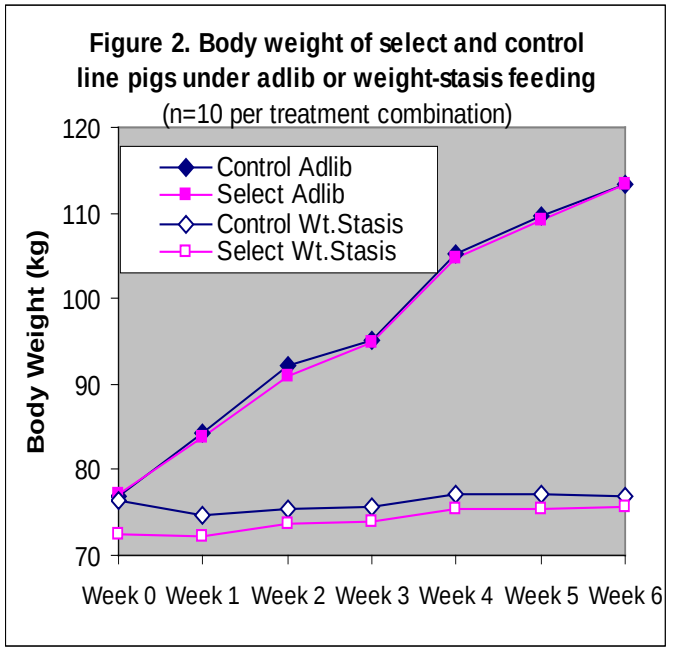
No deletrious responses to selection on reproductive sows

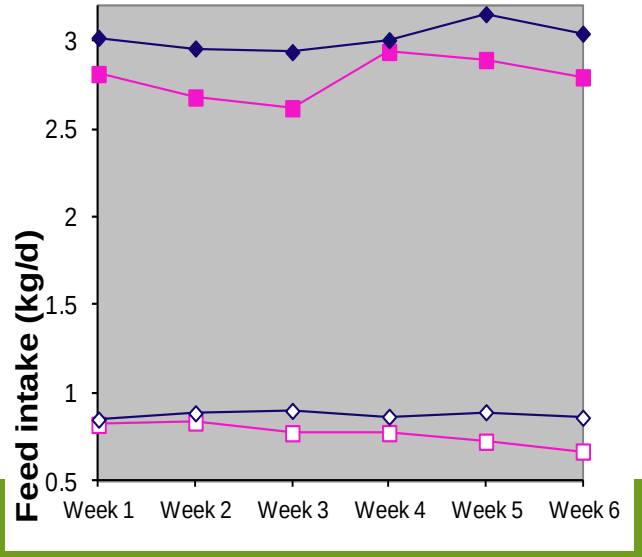
See Renaudeau et al EAAP 2013



Maintenance requirements







LRFI: lowered maintenance requirements

Boddicker et al, 2011
Barea et al, 2010

Energy and protein metabolism

Energy metabolism turned to fast glycolytic in LRFI pigs
Affected proteic turn over

see Gondret et al EAAP 2013

To clarify the relationships between adipose tissue and feed efficiency in growing pigs

Within the LW breed

Body fat = genetics + environment

Divergent selection on **RFI***

6th to 8th generations

Feed restriction

Source of feed energy

*The difference between observed feed intake and expected feed intake (based on growth potential and body composition) *Gilbert et al., 2007*

- Aim of the study

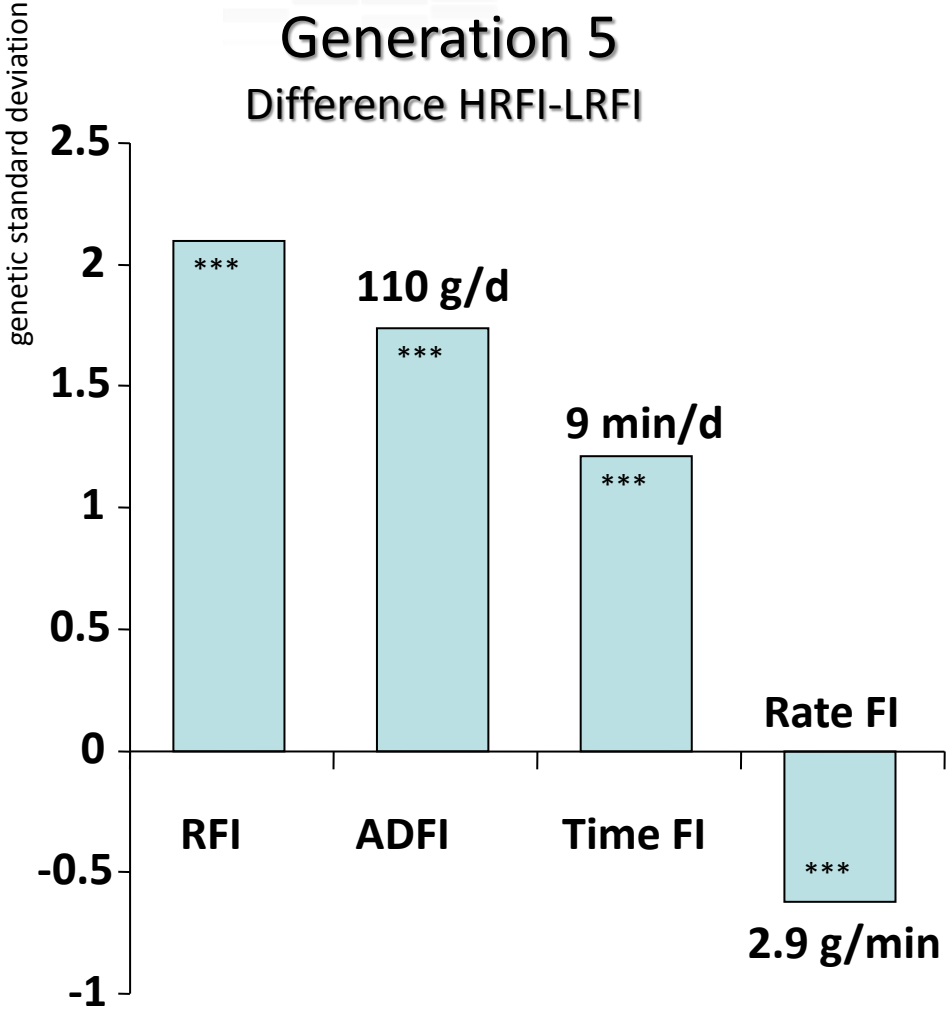
see Louveau et al EAAP 2013

Objectives

- **To determine the influence of RFI selection on the proteome and transcriptome of skeletal muscle of 115 kg pigs**
- **To differentiate variations due to genetic orientation from those related to spontaneous feed intake level**

.04

Feeding behavior



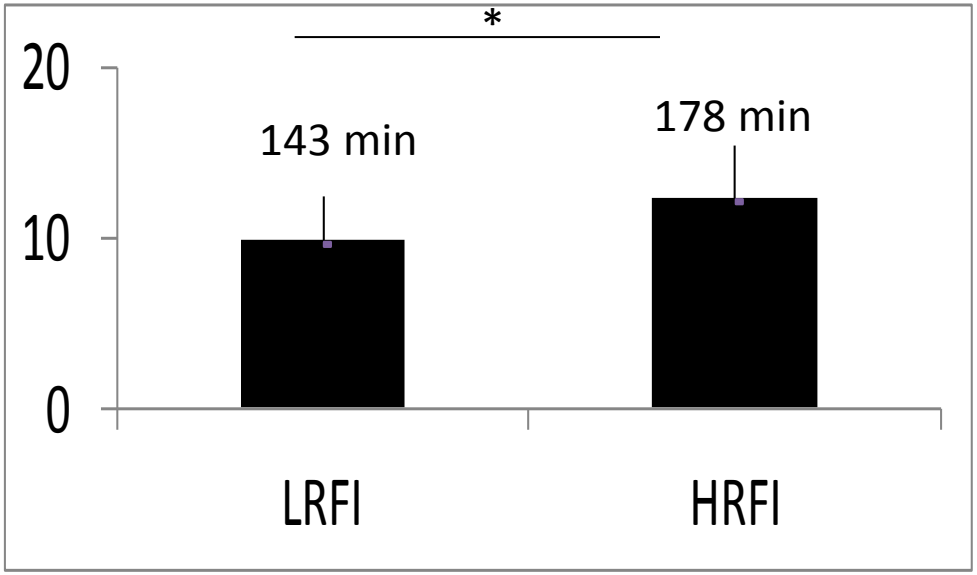
LRFI :
Smaller quantity
Less time for feeding
Fewer visits
Eat faster

➔ **Reduced energy used for feeding behavior**

Young et al, 2011
Gilbert et al, 2009

Activity

% time standing during
a 24h- scan

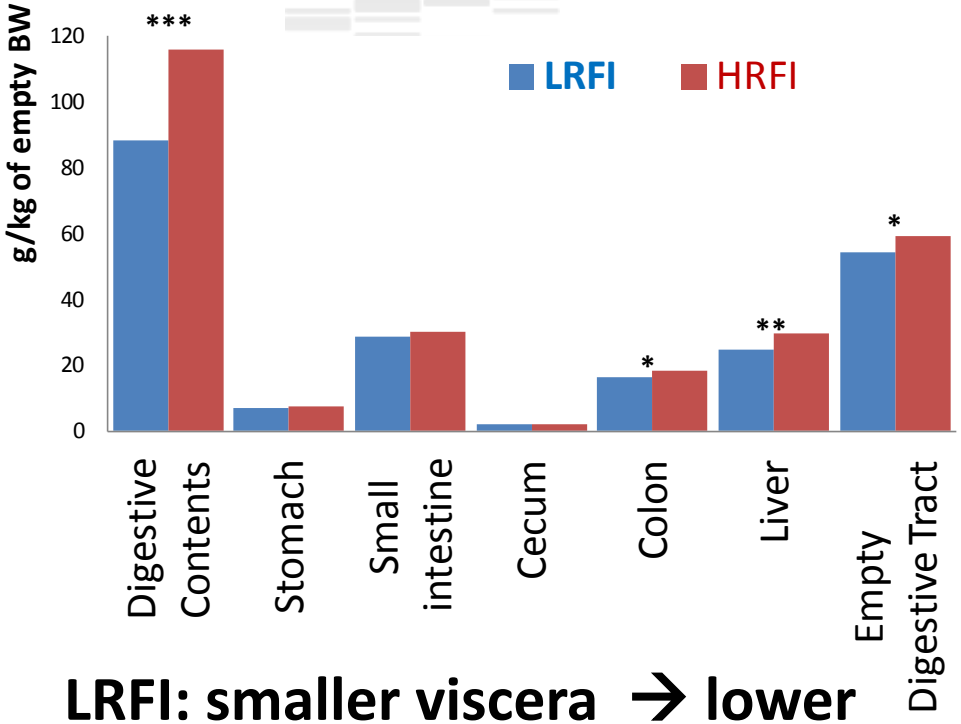


Less standing
Less interactions
(others and substrates)
(but no leg issues)

➔14% line difference for DFI
= activity (INRA)

Saddler et al, 2012
Meunier-Salaün et al, in prep.

Digestive tract /digestive efficiency

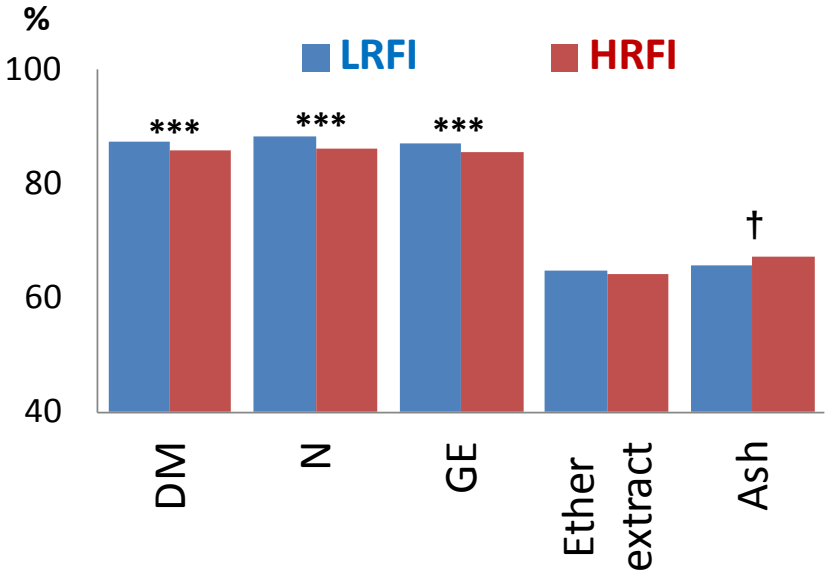


LRFI: smaller viscera → lower maintenance → more energy available (relatively to ADFI) to support growth

ISU: No difference

INRA: no associated increase of digestive efficiency (total or for intestine segments)

ISU: increase of digestive efficiency in LRFI



Barea et al, 2011
Harris et al, 2012
Montagne et al, submitted

Digestive efficiency / high fiber diets

see Montagne et al EAAP 2013

Introduction.

Question of research and aim of the study

- Studies exploring the genetic and physiological basis of RFI mainly considered pigs receiving a non-limiting concentrated diet with a low level of dietary fibre

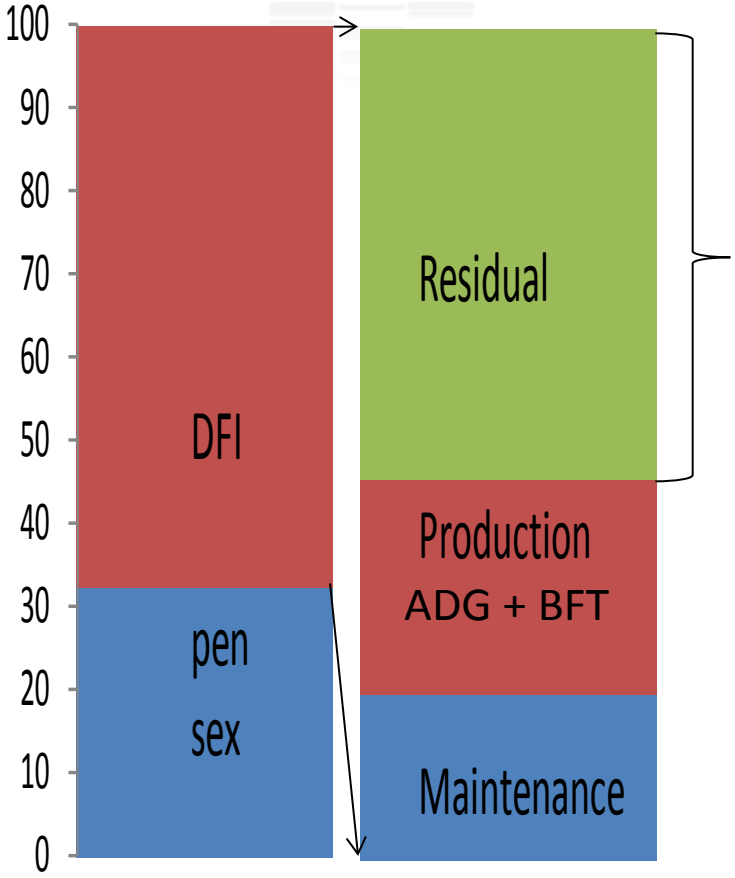
  10-15% NDF and 9.5-10 MJ Net energy / kg *Gilbert et al. (2013)*

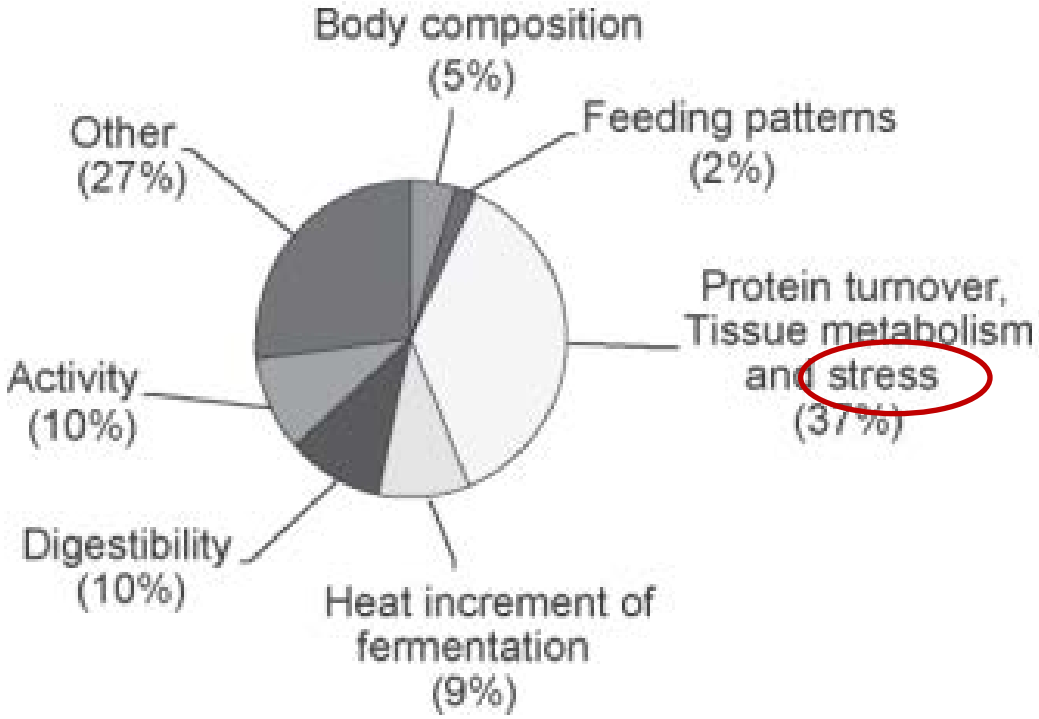
- The impact of RFI selection on the ability of the pigs to valorise a fibre-rich diet remains unknown

Does the selection to lower RFI impacted on the lines' ability to cope with a high fibre diet ?

To measure the performances and feeding behaviour of 2 lines of Large white pigs divergently selected for RFI

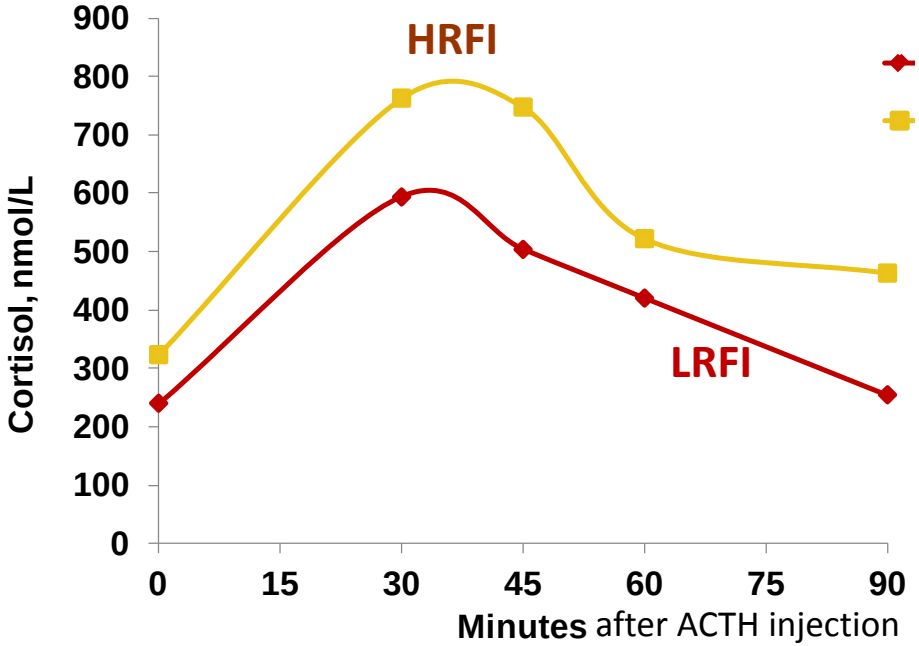
What's in RFI?





Cattle, Herd and Arthur, 2009

HPA axis and ACTH responses



INRA (30 to 60 pigs/line, urine)

No significant line difference

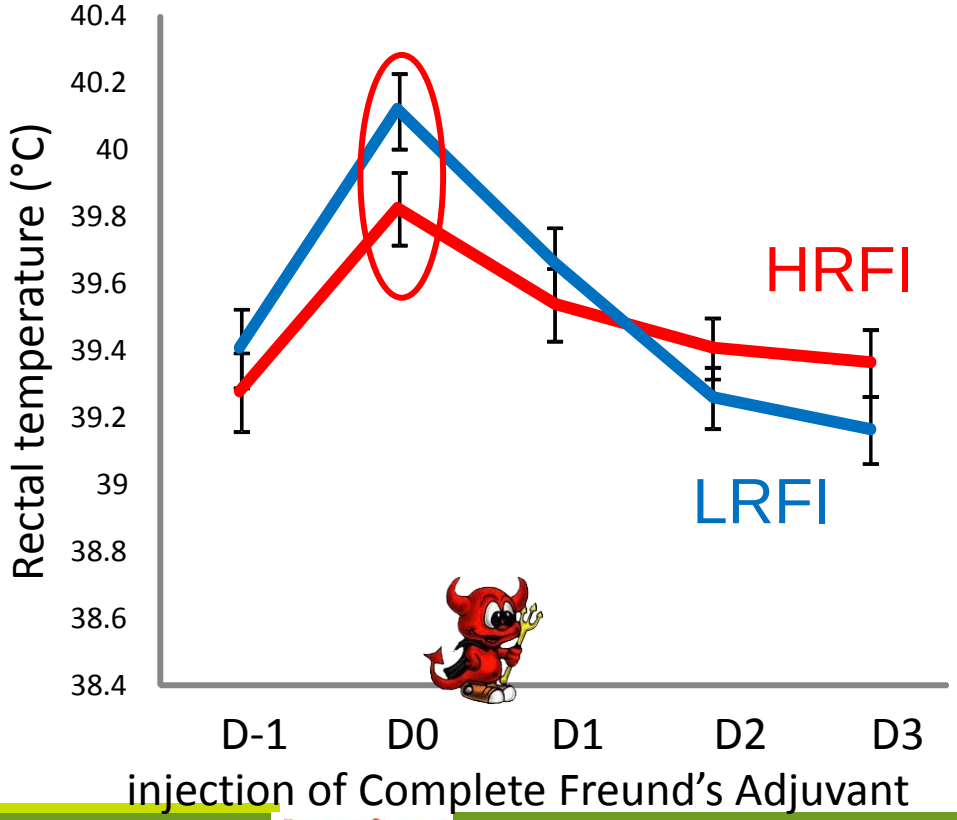
ISU (6 gilts/line, plasma) :

LRFI tended to be less responsive to the challenge . Both lines recovered within 90 min

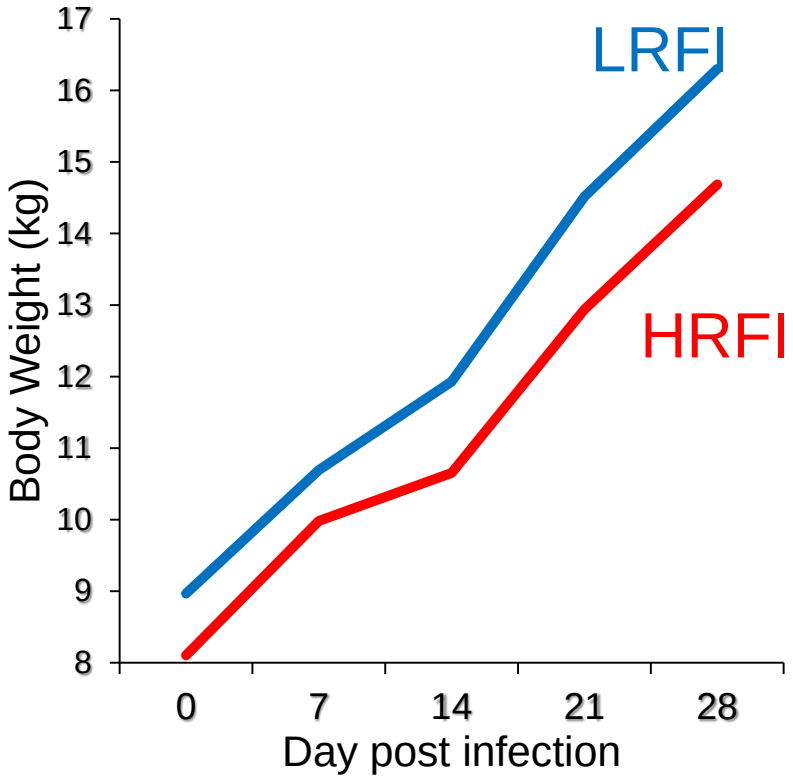
P Mormède, N Gabbler

Inflammatory challenges

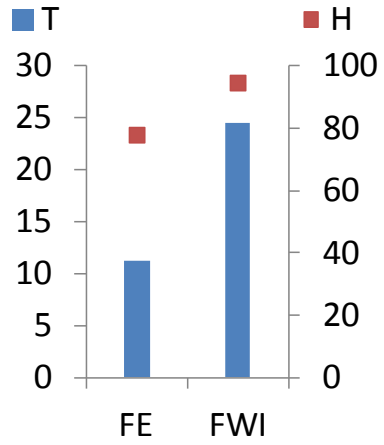
LRFI
better use of nutrients,
faster decrease of inflammation,
lower impact on growth

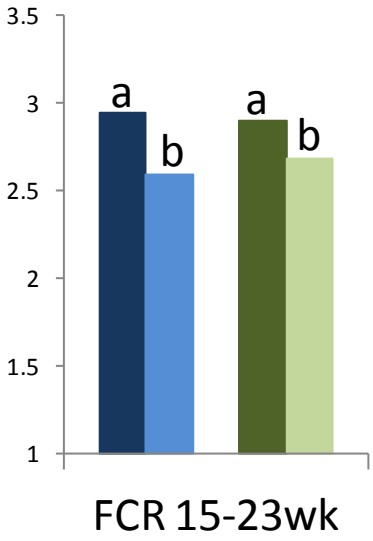


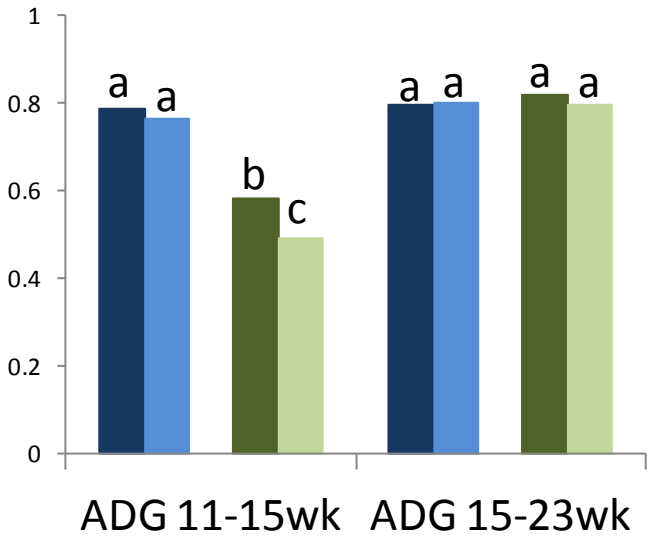
LRFI
no poorer performance
under PRRS challenge

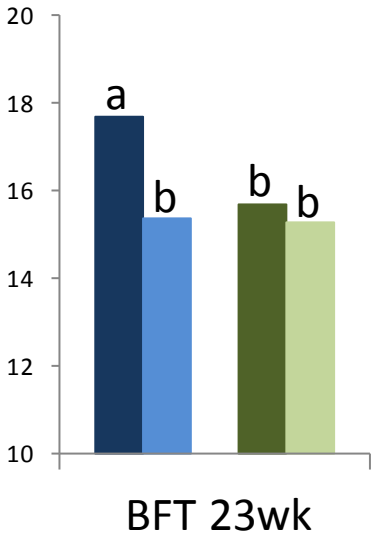


Heat stress









FCR difference reduced → different metabolic responses?

No significant differences in endocrine and metabolite responses during stress

Renaudeau et al
de los Campos, submitted

Summary

- RFI: heritable, responds to selection
- Selection for reduced RFI has resulted in
  - Pigs that eat less but that are slightly leaner (and grow slower)
  - Limited changes in body composition - decreased fatness
  - Limited impact on meat quality
  - Changes in behavior – faster eaters – less active
  - Reduced maintenance requirements, tissue turnover rates
  - Low impact on digestive efficiency (but not challenged?)
- No detrimental impacts on litter size and litter performance
- No detrimental impacts on response to stress …

➔ Selection rules – Biomarkers

Acknowledgements

INRA

Animal Genetics

Physiology and LFS

ACCAF and GISA Metaprograms

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PIC/Genus

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INRA Staff

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Noblet , Renaudeau
Combes

Mormède, Foury
Gourdine
Riquet, Servin
Sellier , JP Bidanel
Rogel-Gaillard, Estellé
Gatellier , Sayd

Grad Students

Faure, Le Naou
De los Campos
Saintilan
Al Aïn, Calderon-Diaz, Le

Post docs

Barea, Hauptli

Collaborators

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J.Bidanel
Australia
Hermesch, Bunter

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ISU faculty

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Lunney, Webber, Kerr
Australia
Bunter, Dunshea
IPG & Wageningen
Bergsma, Knol

RFI Grad Students

Casey, Cai, Young, Boddicker, Thekkoot, Waide, Hess, Gorbach, Couture
Smith, Grubbs, Cruzen, Arkfeld
Mani, Harris
Lhakgvadorj, Saddler
Qu

Post-Docs / Research Assoc.

Onteru, Rakhshandeh, Steadham