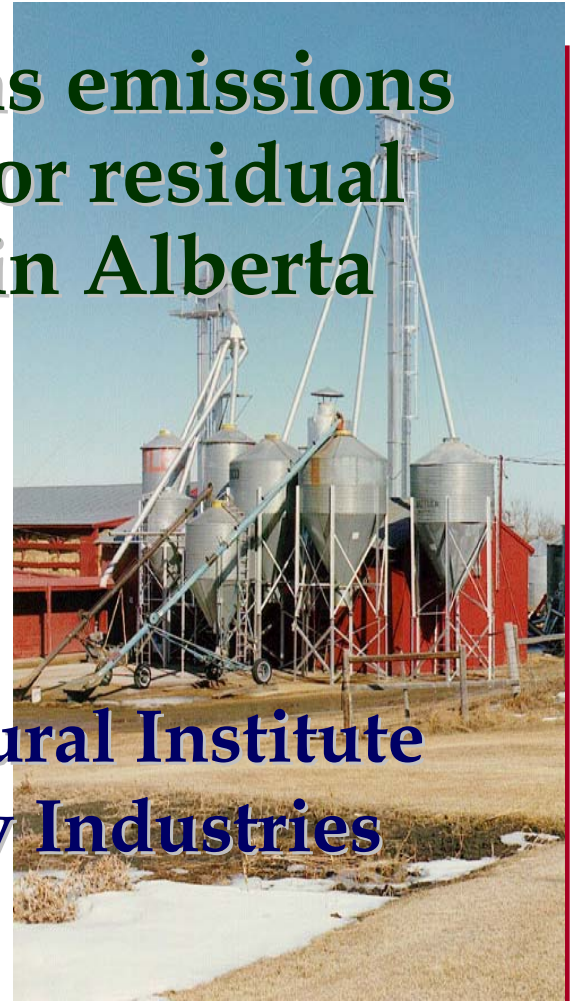


RFI - GHG Workshop (Edmonton)

Reduction in greenhouse gas emissions associated with selection for residual feed intake in beef cattle in Alberta

Paul Arthur, PhD

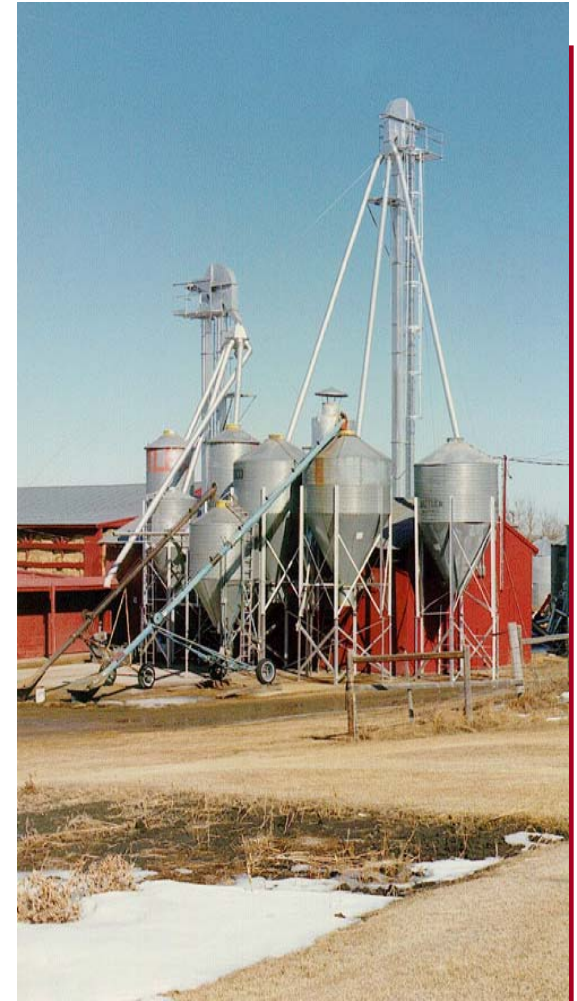
**Elizabeth Macarthur Agricultural Institute
NSW Department of Primary Industries
AUSTRALIA**



What is residual feed intake

~ Outline ~

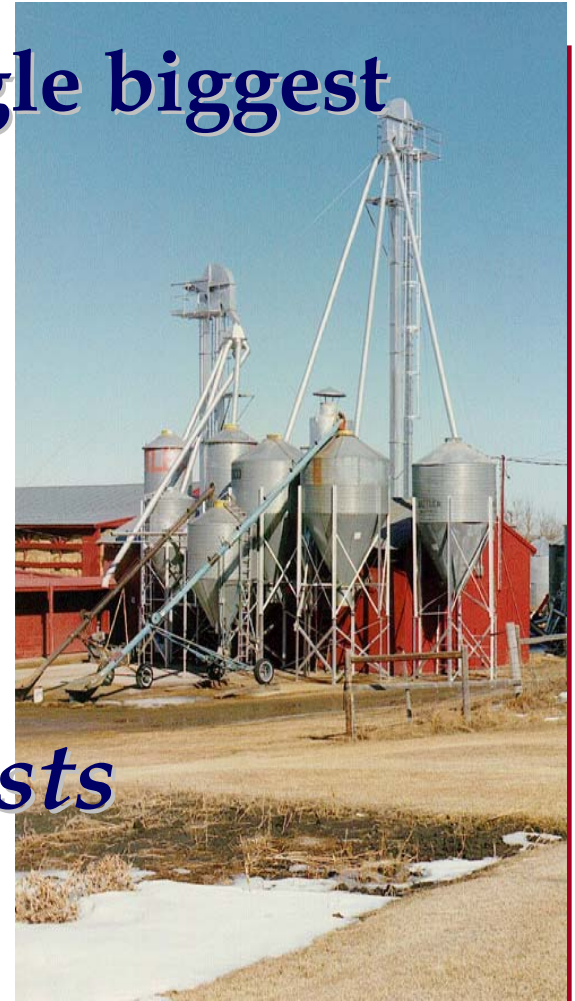
- ❑ Residual feed intake (*RFI*)
 - Definition
 - Genetics
 - Proof of concept ~ Demo herd
- ❑ RFI and greenhouse gas (*GHG*) emissions
- ❑ Conclusions on the science



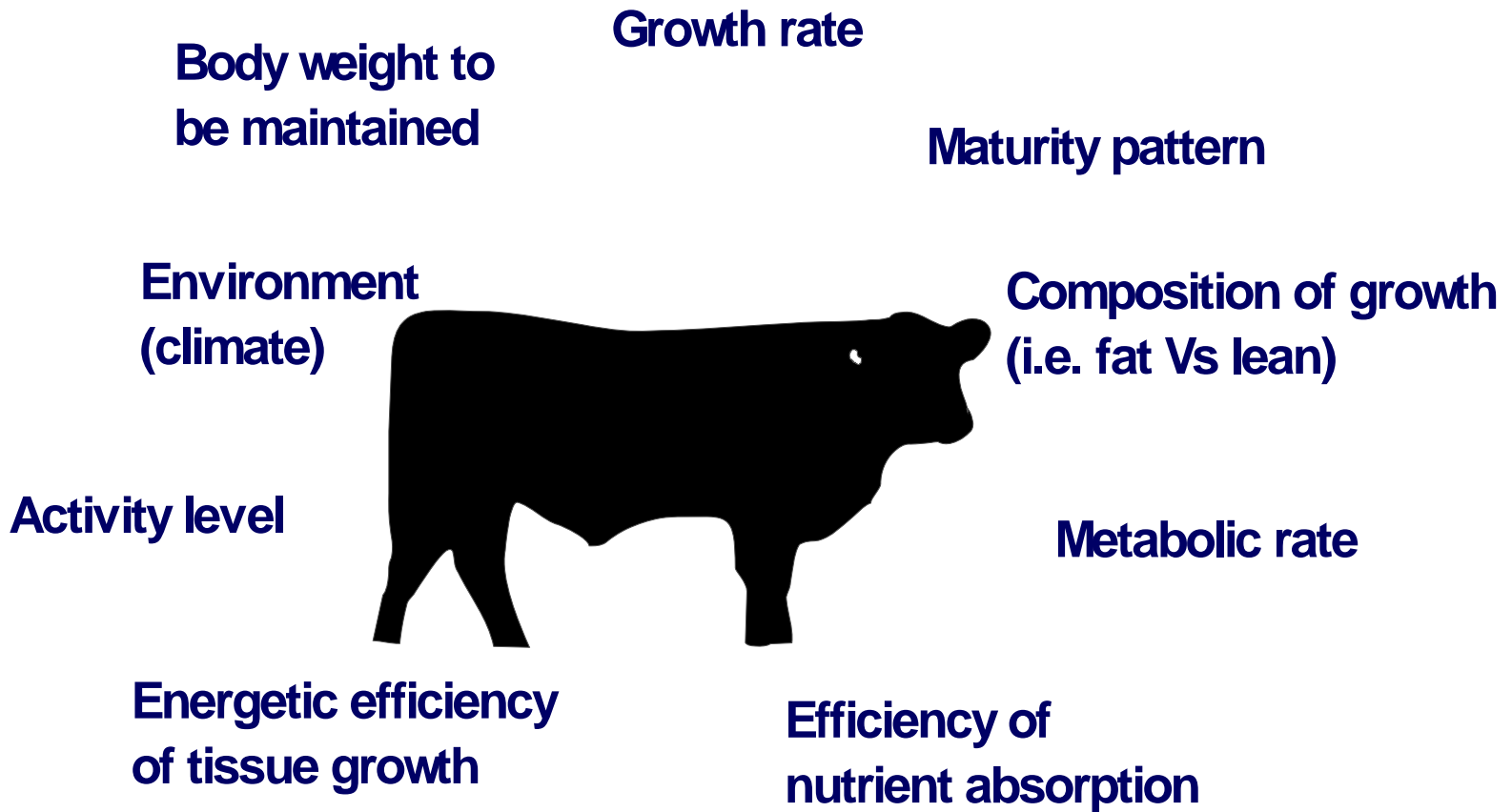
Why residual feed intake?

- ❑ The cost of feed is the single biggest expense in beef production
 - feedlot rations
 - pasture
 - land ownership

Profit \$ = Income - Costs



Factors affecting feed utilization



What is residual feed intake?

- ❑ Feed intake after allowing for the requirements for maintenance and production
- ❑ **In beef cattle** ~ The difference between an animal's actual feed intake and its expected feed intake based on its size and growth over a specified period

Efficient animals have lower or negative values

Computation of RFI

$$RFI = \text{Actual FI} - \text{Expected FI}$$

Expected FI → *feeding standards formulae*

→ *regression*

$$\text{Feed} = a + b_1 (\text{ADG}) + b_2 (\text{Wt}^{0.73}) + \varepsilon$$

By definition, RFI is independent of weight and growth rate of the animals

Practical example

Trait	Bull A
Start weight (kg)	398
End weight (kg)	581
Growth rate (kg/day)	1.54
Fat deposition (mm)	10
Expected feed intake (kg)	13.9
Actual feed intake (kg)	13.2
Residual feed intake (kg/d)	-0.68

Practical example

Trait	Bull A	Bull B
Start weight (kg)	398	386
End weight (kg)	581	569
Growth rate (kg/day)	1.54	1.54
Fat deposition (mm)	10	9

Practical example

Trait	Bull A	Bull B
Start weight (kg)	398	386
End weight (kg)	581	569
Growth rate (kg/day)	1.54	1.54
Fat deposition (mm)	10	9
Expected feed intake (kg)	13.9	13.7
Actual feed intake (kg)	13.2	15.7
Residual feed intake (kg/d)	-0.68	+2.00

Genetics of RFI

Source

Heritability

Pre 2000 reports

Range 0.14 to 0.28

Herd and Bishop (2000)

0.16 ± 0.08

Arthur *et al.* (2001a)

0.39 ± 0.03

Arthur *et al.* (2001b)

0.39 ± 0.04

Robinson and Oddy (2004)

0.18 ± 0.06

Schenkel *et al.* (2004)

0.38 ± 0.07

Hoque *et al.* (2006a)

0.24 ± 0.11

Nkrumah *et al.* (2007a)

0.21 ± 0.12

RFI is moderately heritable ~ same as growth

Correlations with growth traits

Trait	Lowest	Highest	Comments
Feed intake	0.43 ±0.15	0.81*	<i>Med to High</i>
ADG	-0.04 ±0.08	0.25 ±0.16	<i>Basically zero</i>
Metabolic wt	-0.20 ±0.16	0.22 ±0.29	<i>Basically zero</i>

Correlations with growth traits

Trait	Lowest	Highest	Comments
Feed intake	0.43 \pm 0.15	0.81*	<i>Med to High</i>
ADG	-0.04 \pm 0.08	0.25 \pm 0.16	<i>Basically zero</i>
Metabolic wt	-0.20 \pm 0.16	0.22 \pm 0.29	<i>Basically zero</i>
Weaning wt		0.34 \pm 0.34	<i>Basically zero</i>
Yearling wt	0.15 \pm 0.29	0.32 \pm 0.10	<i>Basically zero</i>
Scrotal circumference	-0.03 \pm 0.11	0.15 <i>ns</i>	<i>Basically zero</i>

Correlations with body composition

Trait	Lowest	Highest	Comments
<i>Eye muscle area</i>			
Ultrasound	0.09 ±0.09	-0.17 <i>ns</i>	<i>Basically zero</i>
Carcass	-0.24 ±0.26	-0.45 ±0.29	<i>Zero?</i> <i>Low -ve?</i>

Correlations with body composition

Trait	Lowest	Highest	Comments
<i>Eye muscle area</i>			
Ultrasound	0.09 ±0.09	-0.17 <i>ns</i>	<i>Basically zero</i>
Carcass	-0.24 ±0.26	-0.45 ±0.29	<i>Zero? Low -ve?</i>
<i>Rib fat depth</i>			
Ultrasound	0.16 <i>ns</i>	0.17 ±0.05	<i>Low (+)ve</i>
Carcass	0.48 ±0.12	0.27 ±0.20	<i>Med?/Low +ve</i>

Correlations with body composition

Trait

<i>Marbling</i>	Ultrasound	Carcass	Comments
Score	-0.02 <i>ns</i>	-0.50 ±0.31	<i>Zero? Low?</i>
Chemical		0.22 ±0.17	<i>Zero? Low?</i>

Lifetime repeatability of RFI

□ RFI-P versus RFI-F: r_g 0.65 to 0.75

➤ Arthur et al. 2001

➤ Johnston et al. 2007

□ Low RFI cattle are more efficient on pasture relative to High RFI cattle

➤ Herd et al. 2004

□ RFI-P versus RFI-Cow: r_g of 0.75 to 0.99

➤ Archer et al. 2002

A high proportion of the same genes control the expression of RFI throughout the animals life

Summary of genetic parameters

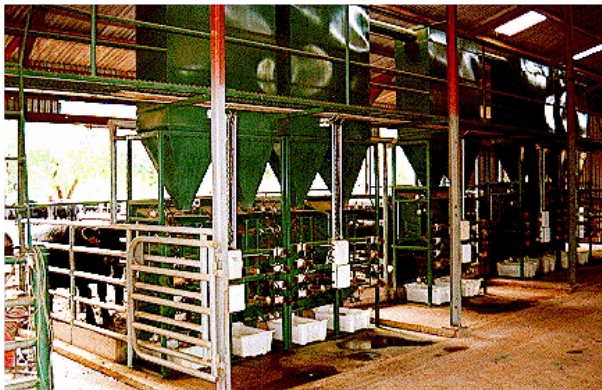
- ❑ RFI, like growth, is moderately heritable
- ❑ RFI is positively correlated with feed intake
 - ~ Low RFI animals eat less
- ❑ Growth and carcass traits are not correlated with RFI
- ❑ There is a low correlation between RFI and fatness
 - ~ Low RFI animals have slightly reduced fat

Progeny of Low RFI parents will eat less feed than their High RFI contemporaries

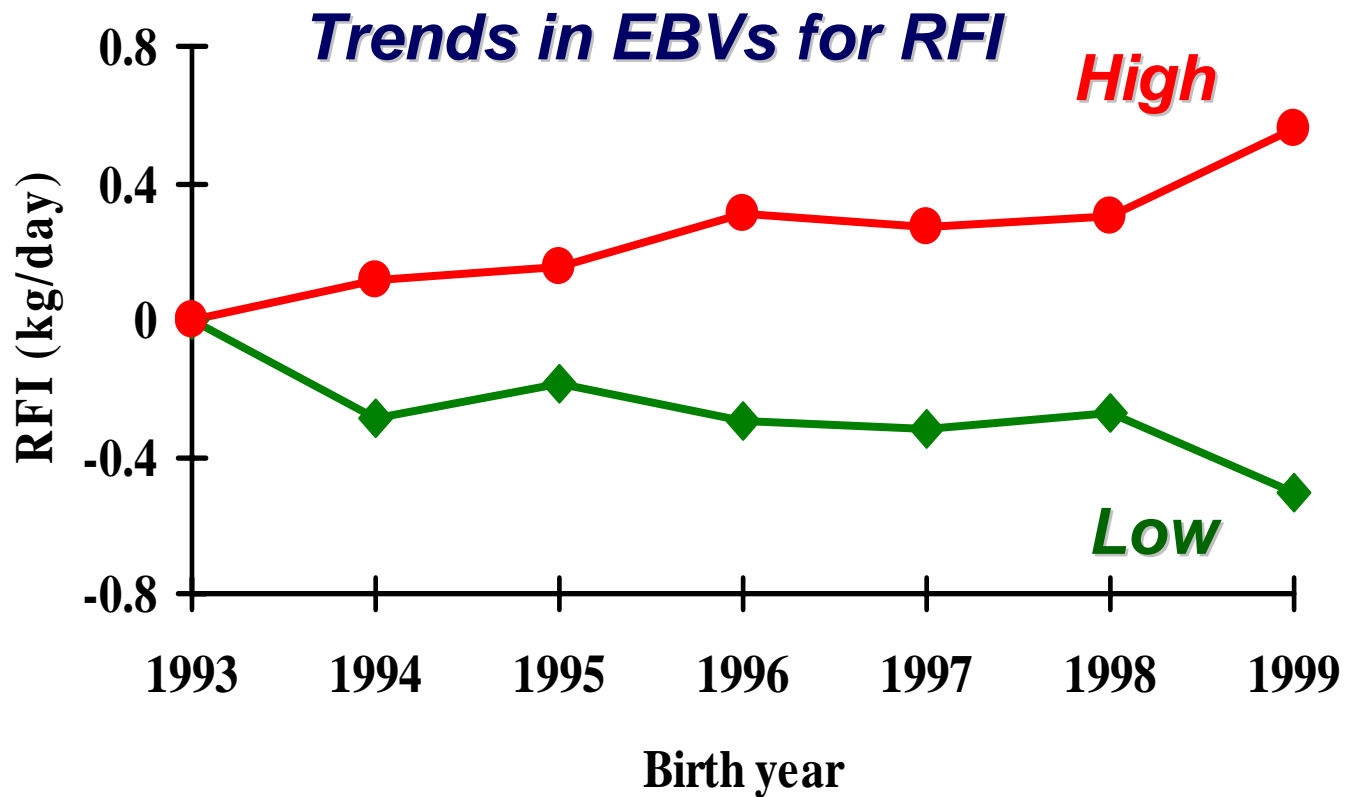
Proof of concept demonstration

Trangie Agricultural Research Centre

Selection on practice



RFI Selection in practice



Selection response – growth on test

Trait	Selection line		Significance
	Low RFI	High RFI	
Weaning wt, kg	232.5	228.3	<i>ns</i>
Yearling wt, kg	384.3	380.7	<i>ns</i>
ADG, kg	1.44	1.40	<i>ns</i>
Rib fat, cm	5.3	7.2	*
Feed intake, kg/day	9.4	10.6	*
RFI, kg/day	-0.54	0.71	*

2.0 generations of selection

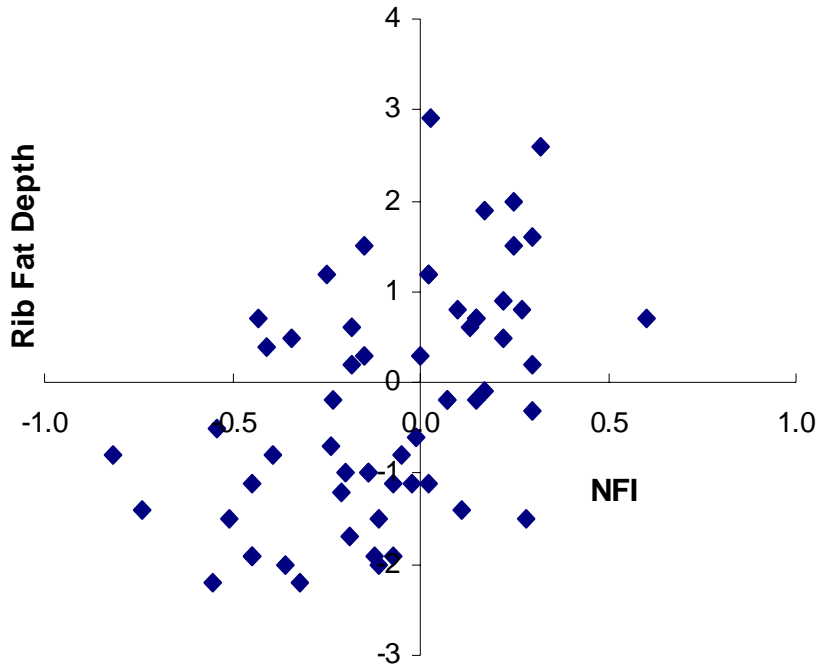
Selection response – Carcass

Trait	RFI group		Significance
	Low RFI	High RFI	
Final wt (kg)	518	521	<i>ns</i>
Carcass wt (kg)	291	295	<i>ns</i>
Grade fat, mm	8.8	11.6	*
Marbling score	2.3	2.4	<i>ns</i>

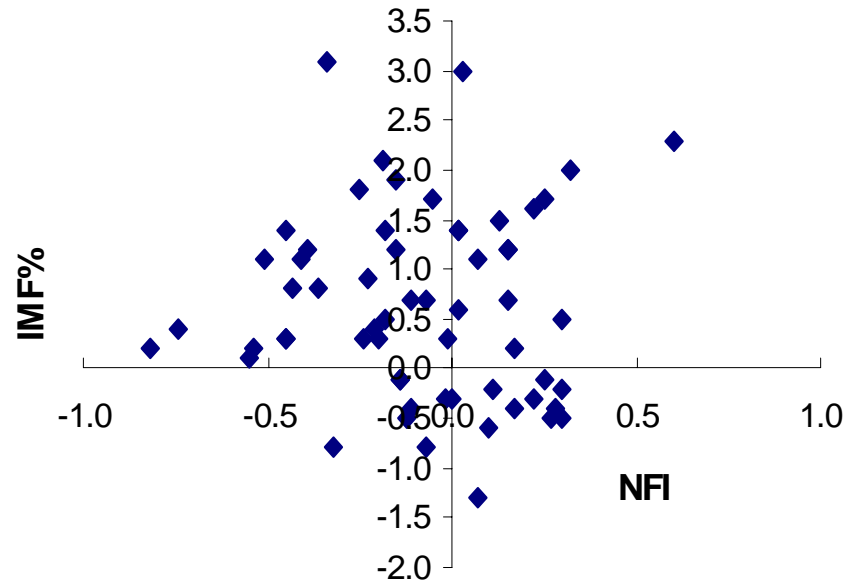
Nkrumah et al. 2004 _ Alberta

Has reduced fat got you worried?

(a) Rib Fat EBV v NFI EBV

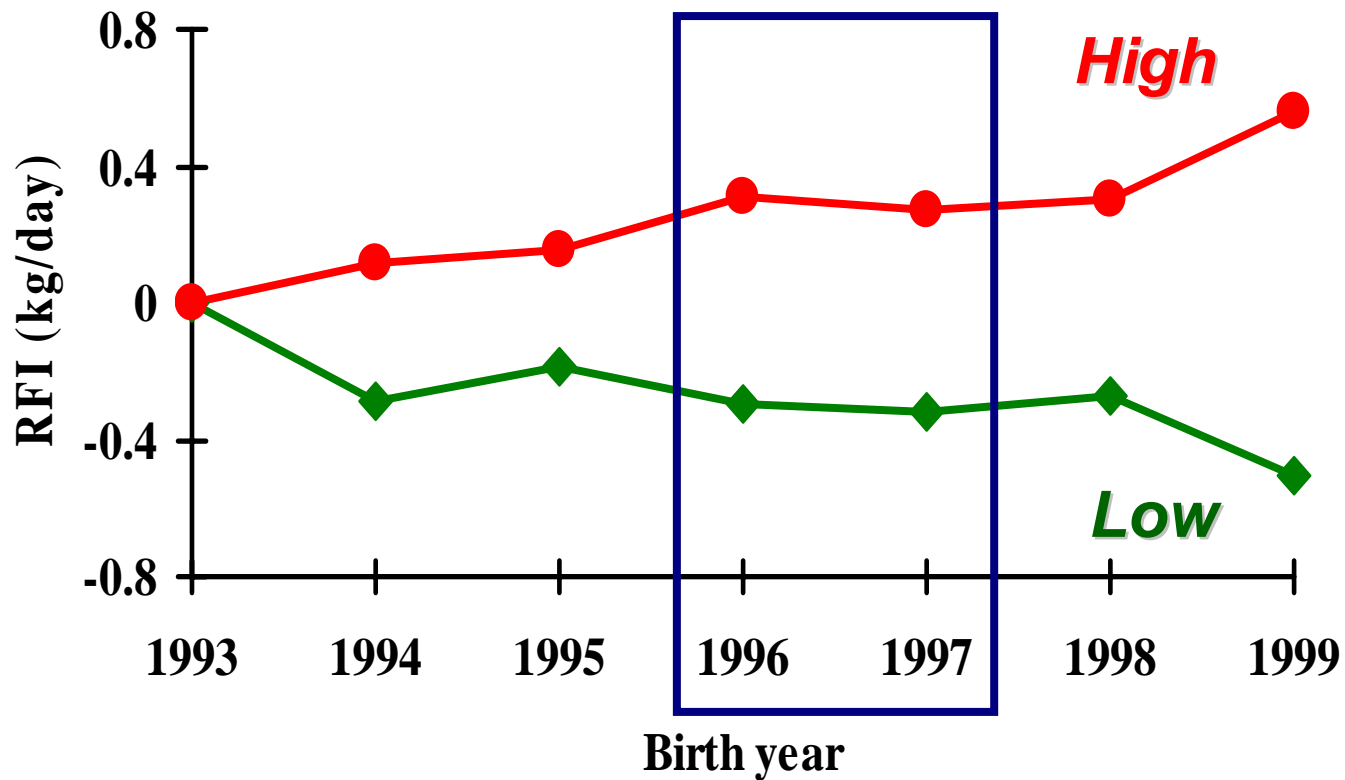


(b) IMF EBV v NFI EBV



Angus Bulls (born since 1985); 2005 EBVs

Selection response – meat quality



1.0 generations of selection

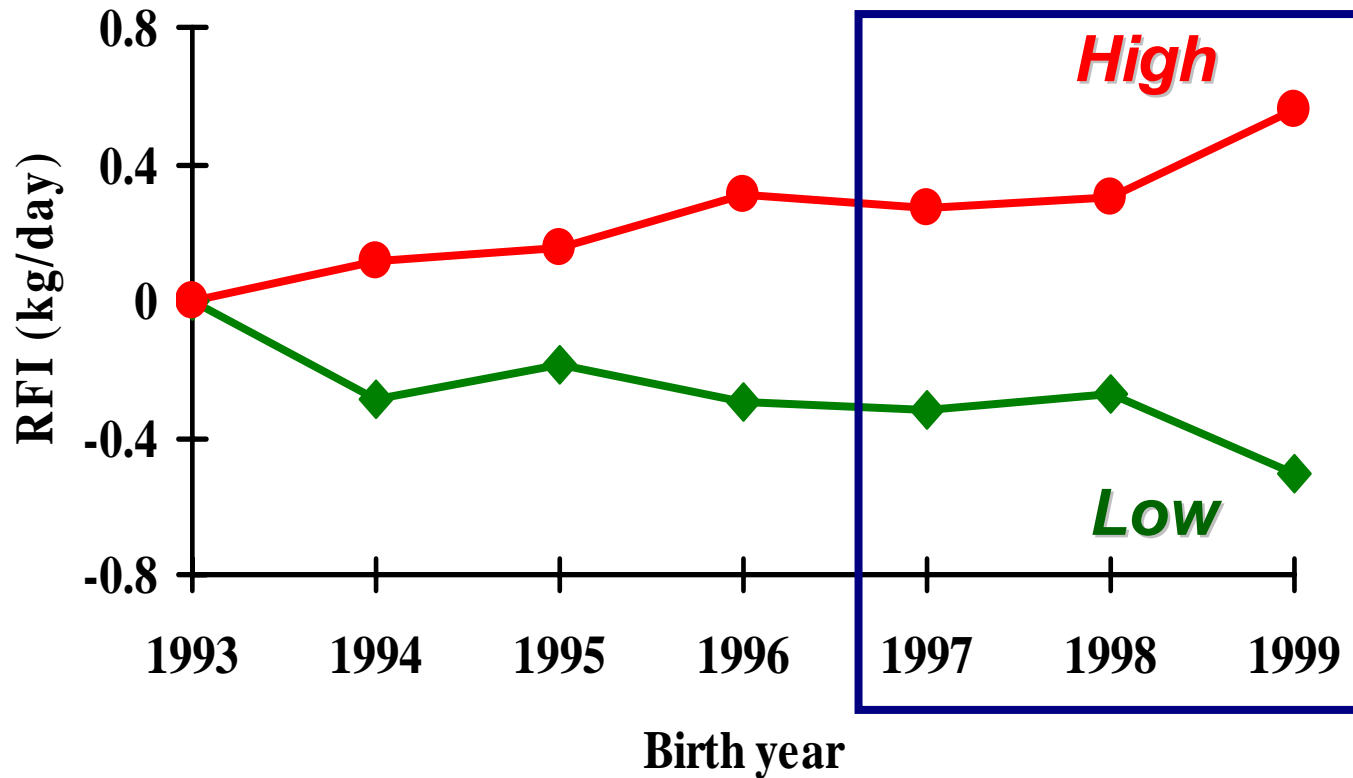
Selection response – meat quality

Trait	Selection line		Significance
	Low RFI	High RFI	
Shear force (kg) <i>units/g tissue</i>	4.6	4.6	<i>ns</i>
<i>m</i> -calpain	1.9	1.8	<i>ns</i>
μ -calpain	2.3	2.1	<i>ns</i>
Calpastatin	5.2	4.6	*

Selection response – reproduction

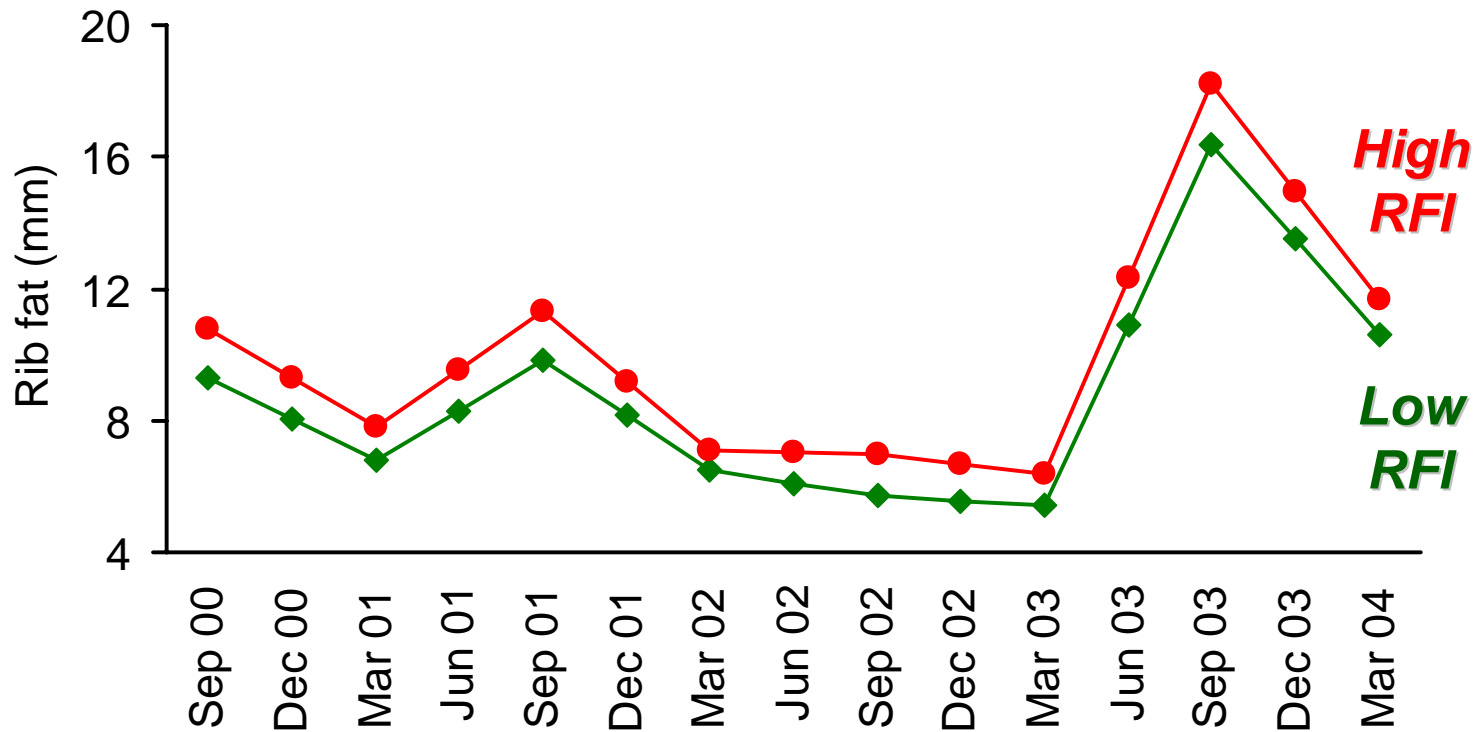


Selection response – reproduction



1.5 generations of selection

Selection response - cow rib fat



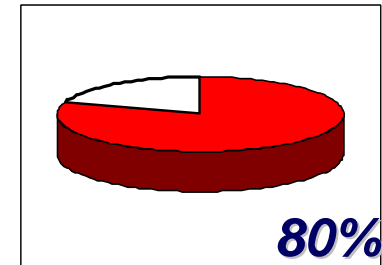
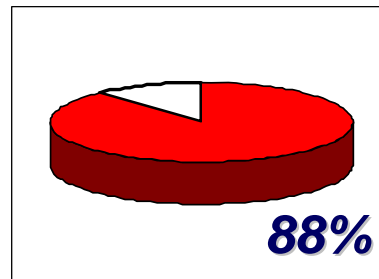
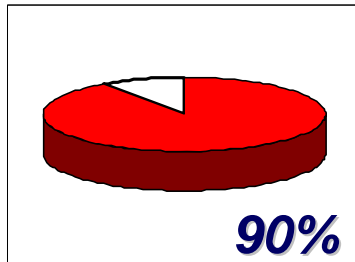
Selection response – reproductive rates

Pregnancy

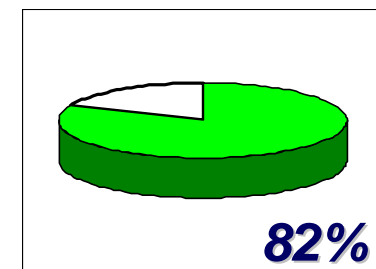
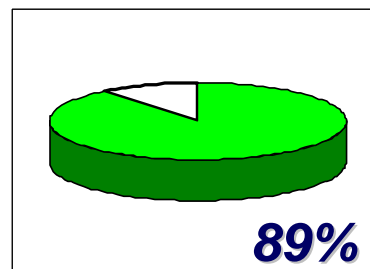
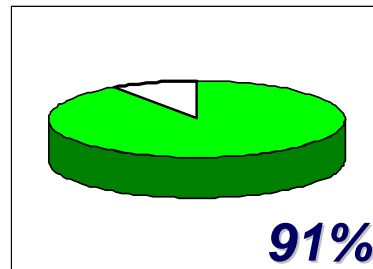
Calving

Weaning

High RFI



Low RFI



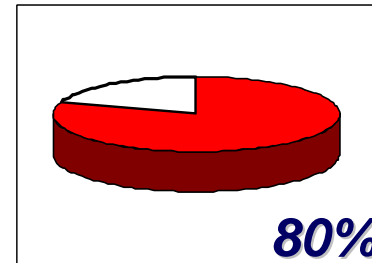
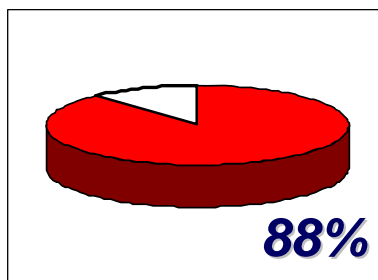
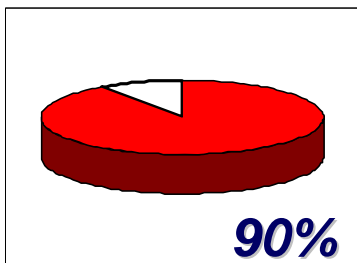
Selection response – reproductive rates

Pregnancy

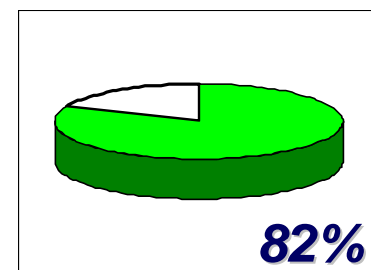
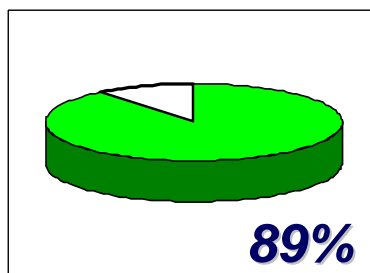
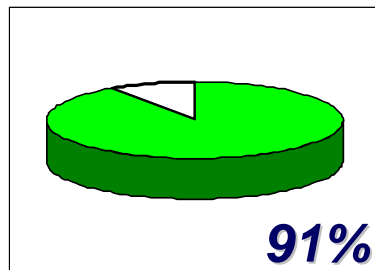
Calving

Weaning

High RFI



Low RFI



Trait

Low RFI

High RFI

Calving date

215 ± 2

210 ± 1

Genetics of RFI ~ Conclusion

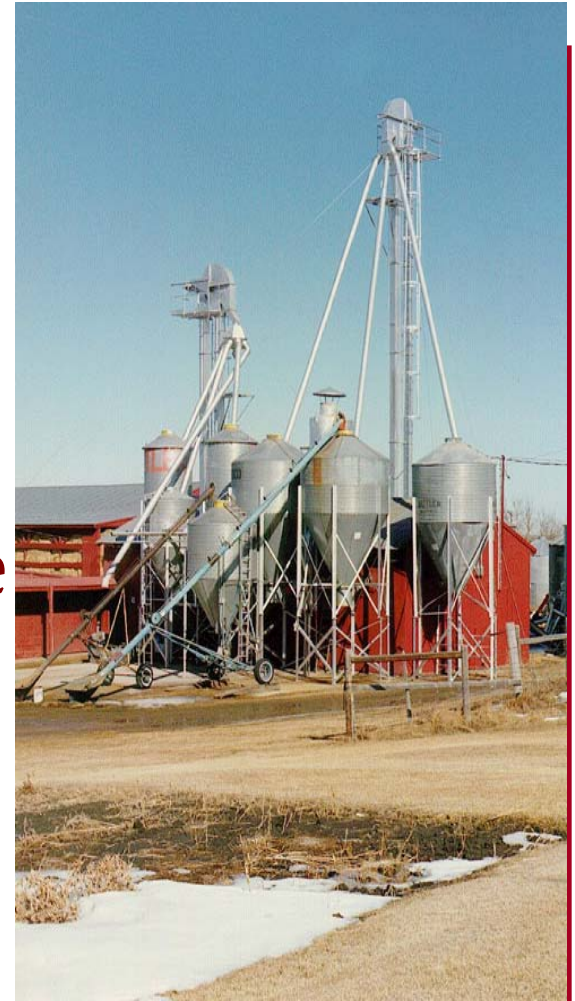
Improvement in feed efficiency can be made through selection for Low RFI



Low RFI cattle consume less feed than unselected and High RFI cattle at the same level of production

Outline

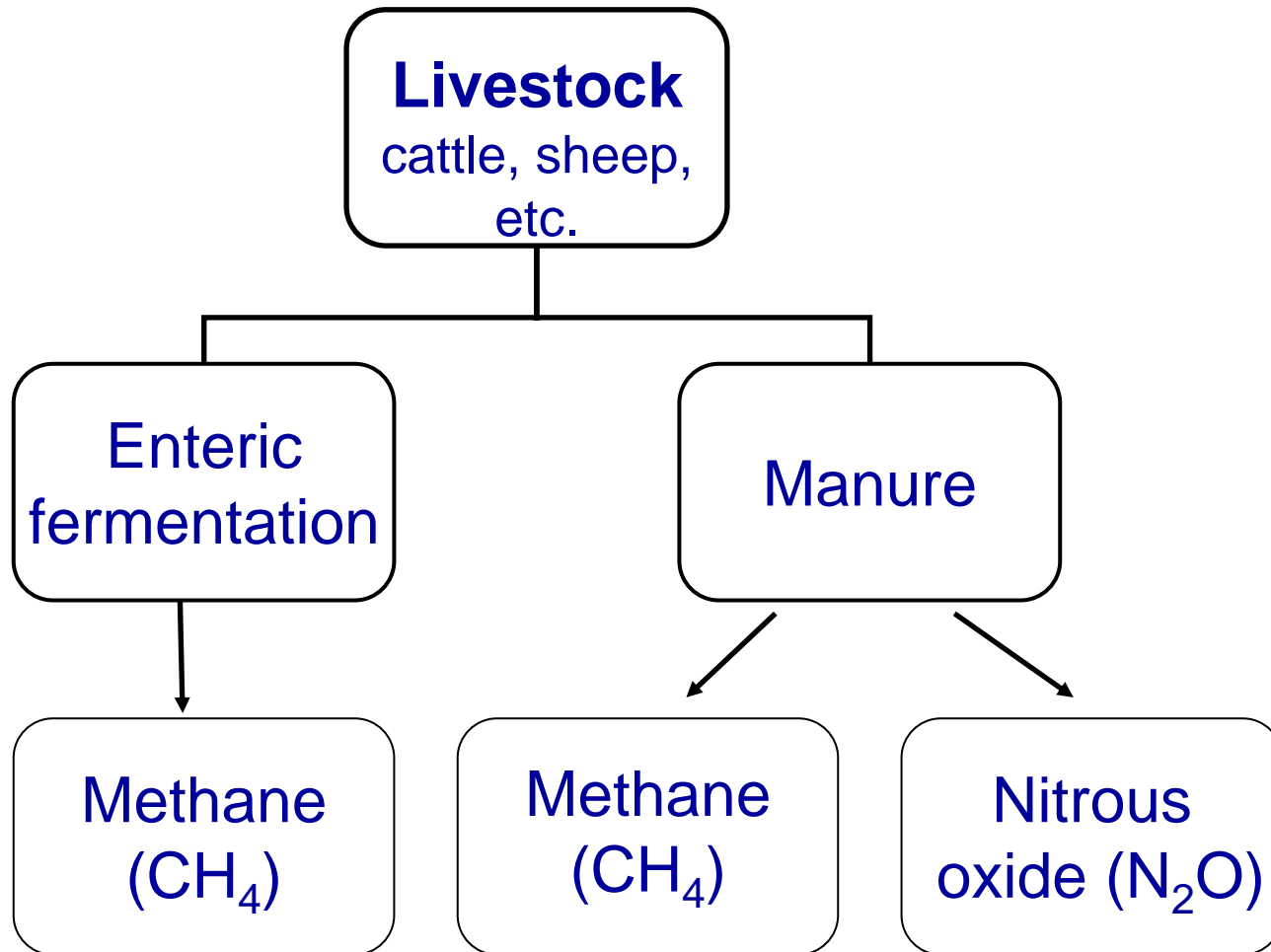
- ❑ Objectives and scope
- ❑ Residual feed intake (*RFI*)
- ❑ *RFI* and greenhouse gas (*GHG*) emissions
- ❑ Conclusions on the science



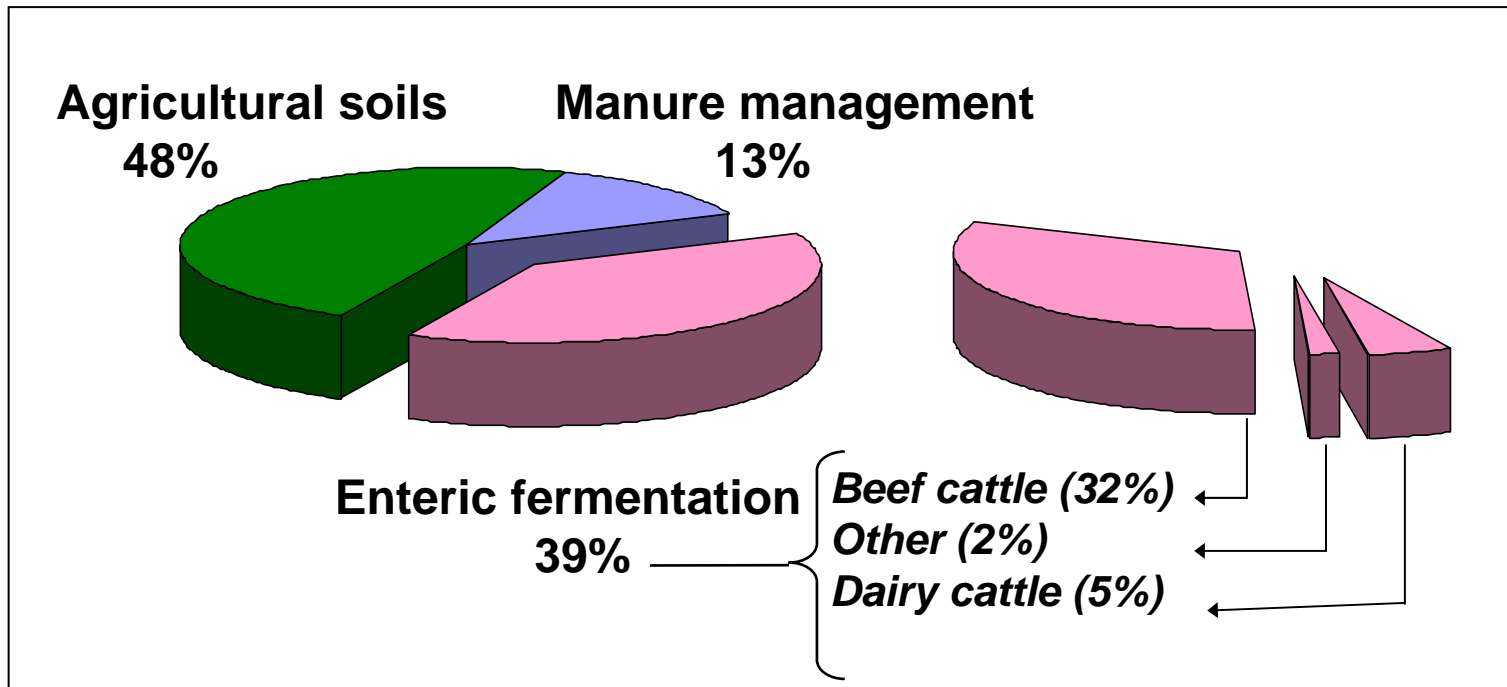
RFI and GHG emissions



GHG emissions from livestock



GHG emissions from agric sector



Environment Canada data for 2006

Feed intake and methane

❑ For cattle on the same feedstuff

High feed intake = high methane

- Blaxter and Clapperton (1965)
- Pelchen and Peters (1998)
- Several others

❑ In cattle

Lower feed intake = low productivity

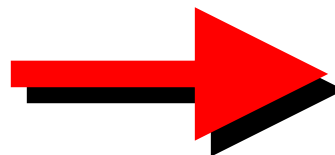
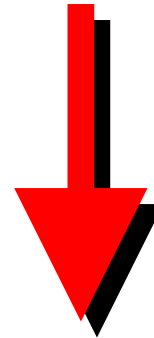
❑ What is unique about RFI?

Genetics of RFI ~ Conclusion

Improvement in feed efficiency can be made through selection for Low RFI



Low RFI cattle consume less feed than unselected and High RFI cattle at the same level of production



RFI and methane production

Desktop calculations of methane

Theoretical evidence provided by :

Okine et al. 2001

Herd et al. 2002

Low RFI versus High RFI cattle

- ❖ ***15-21% reduction in methane emissions***
- ❖ ***15% reduction in methane from manure***
- ❖ ***17% reduction in nitrous oxide from manure***

RFI and methane production

Actual experiments measuring methane

*Empirical evidence
provided by :*

Nkrumah et al. 2006

Hegarty et al. 2007

- ❖ **15-30% reduction in methane emissions**
- ❖ **15-20% reduction in manure production**



Conclusions on the Science

- ❑ RFI, like growth, is moderately heritable
- ❑ RFI is positively correlated with feed intake
~ Low RFI animals eat less
- ❑ Most economically important traits are not correlated with RFI
- ❑ Progeny of Low RFI parents will eat less feed than their unselected or High RFI contemporaries
- ❑ Low RFI cattle have lower GHG emissions than their unselected or High RFI contemporaries

RFI ~ Solid scientific evidence

- ❑ Arthur et al. (2001)
- ❑ Nkrumah et al. (2006)
- ❑ Hegarty et al. (2007)
- ❑ Nkrumah et al, (2007)

Journal of
Animal Science

HOME | HELP | FEEDBACK | SUBSCRIPTIONS | ARCHIVE | SEARCH

Institution: Librarian Agricultural Research Inst | [Sign In via User I](#)

RFI ~ Solid scientific evidence

Journal of
Animal Science

HOME HELP FEEDBACK SUBSCRIPTIONS ARCHIVE SEARCH

Institution: Librarian Agricultural Research Inst | [Sign In via User Name/Password](#)

QUICK SEARCH:		[advanced]
Author:	Keyword(s):	
Go	<input type="text"/>	<input type="text"/>
Year:	Vol:	Page:
<input type="text"/>	<input type="text"/>	<input type="text"/>

The 50 Most-Frequently Cited Articles

in J. Anim Sci. as of March 1, 2009 -- updated monthly

Most-cited rankings are recalculated at the beginning of the month.

Rankings are based on citations to articles on this journal site from articles in [HighWire-hosted journals](#).

23. P. F. Arthur, J. A. Archer, D. J. Johnston, R. M. Herd, E. C. Richardson, P. F. Parnell

Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle

Nov 01, 2001; 79: 2805-2811.

(In "Journal Article") [\[Abstract\]](#) [\[PDF\]](#)

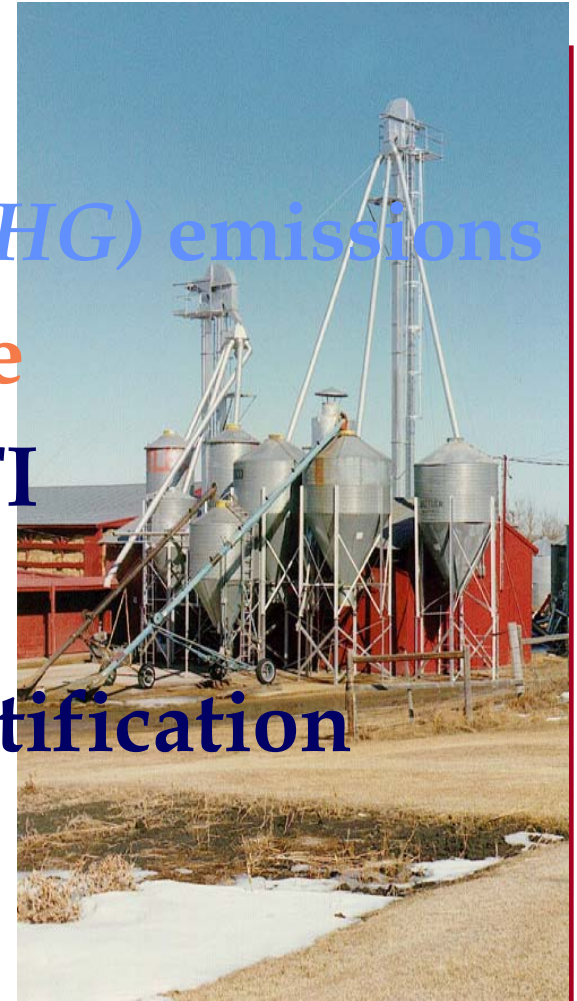
Thanks



How might we develop the protocol

~ Outline ~

- ❑ Residual feed intake (*RFI*)
- ❑ *RFI* and greenhouse gas (*GHG*) emissions
- ❑ **Conclusions on the science**
- ❑ Industry application of *RFI*
- ❑ Recommendations
- ❑ Procedures for *GHG* quantification
- ❑ Protocol specific issues



Industry application for RFI

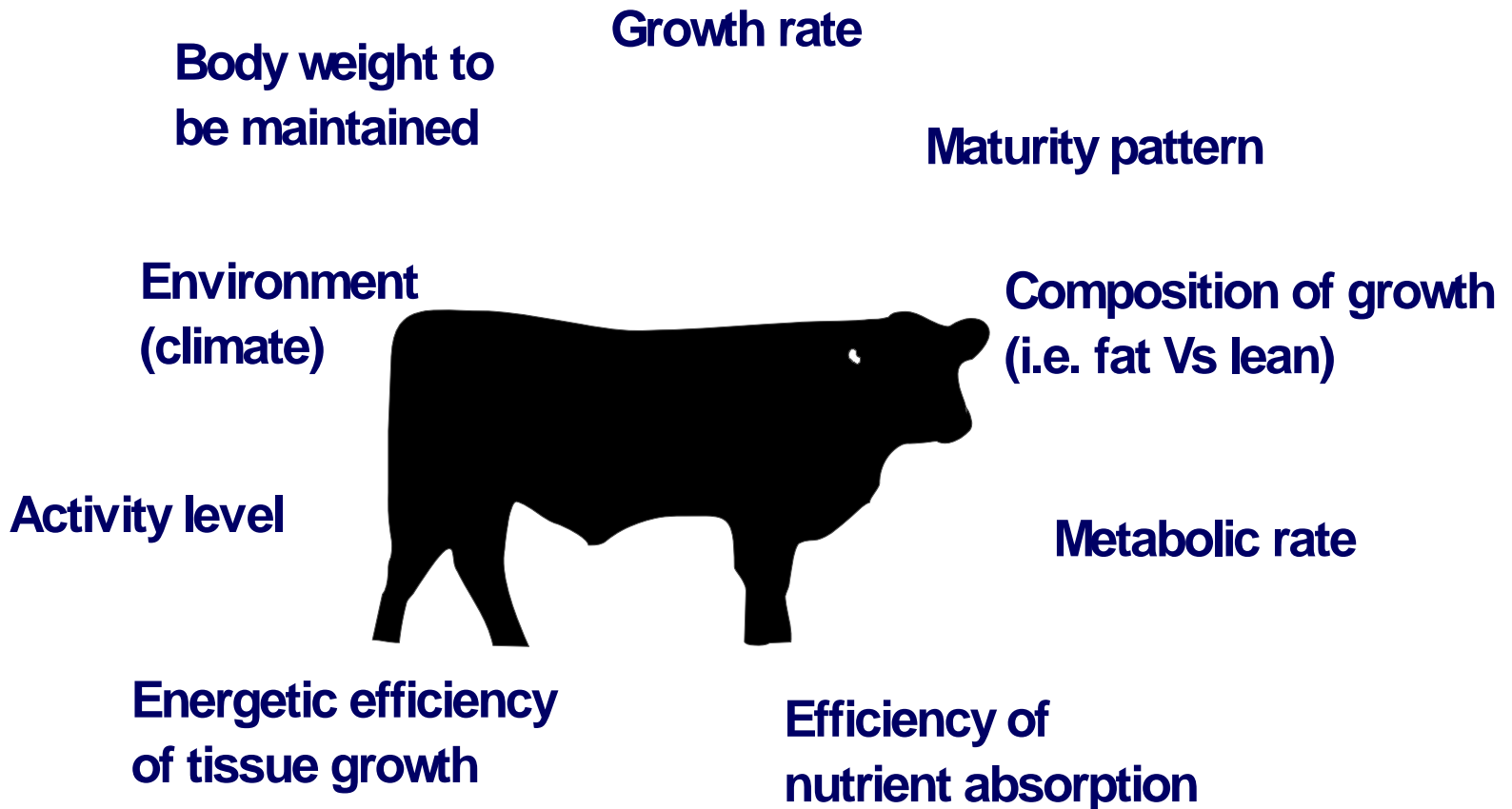
$$\text{Feed} = a + b_1 (\text{ADG}) + b_2 (\text{Wt}^{0.73}) + \varepsilon$$

What do we need?

Accurate and comparable measurement of:

- ❖ Feed intake
- ❖ Body weight
- ❖ Body composition???

Standard protocols – Why?



Standard protocols – Why?

March 2001



Testing Beef Cattle for
Net Feed Efficiency

STANDARDS MANUAL




NSW Agriculture


MEAT & LIVESTOCK
AUSTRALIA

*Performance
Beef Breeders Association*

Standardize / Specify

- Age (postweaning / finishing)
- Sex
- Formulae used
- Test duration
- Diet composition
-

Archer et al. 1997
Wang et al. 2006

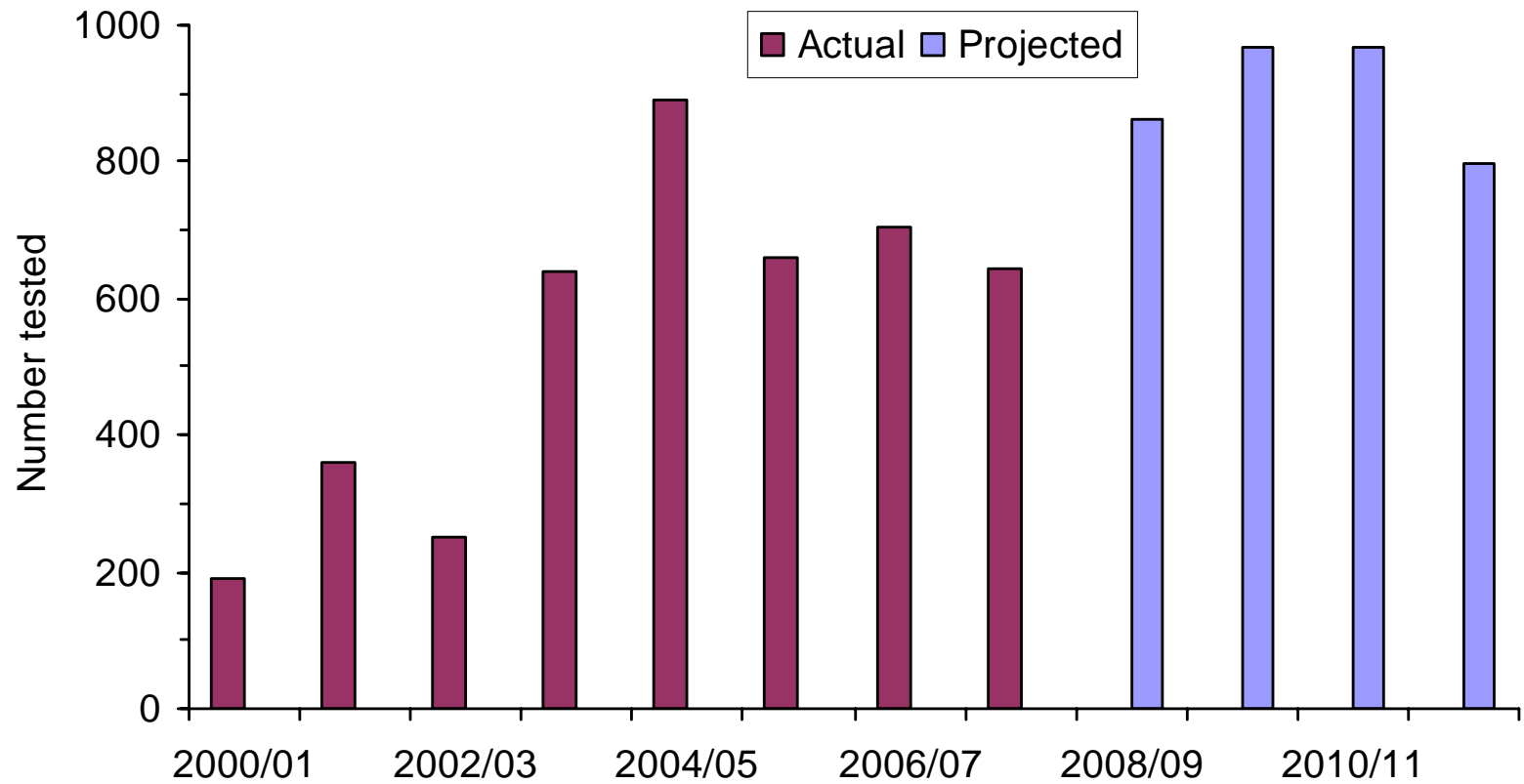
RFI testing facilities

Location	Owner	Annual capacity
Airdrie	Morrison	406
Olds	Olds College	140
Strathmore	Cattlelands	560
Strathmore	Namaka	392
Kinsella	U of A	280/1000
Lacombe	AARD	224
Lethbridge	A&A-F Canada	504

Growsafe systems Ltd



RFI testing in Alberta



Economics of production benefits

Trait	Bull A	Bull B
Start weight (kg)	398	386
End weight (kg)	581	569
Growth rate (kg/day)	1.54	1.54
Fat deposition (mm)	10	9
Expected feed intake (kg)	13.9	13.7
Actual feed intake (kg)	13.2	15.7
Residual feed intake (kg/d)	-0.68	+2.00

Difference in feed cost over 120 days = \$65

Economics of production benefits

- *“Assuming a feed cost of \$0.101 per kg, a daily intake difference of 2.50 kg translates to feed cost savings of \$0.25 per animal per day, or \$37.87 per animal over a typical 150-day finishing period.”*

Crews 2005; Genet. Mol. Res.

- *“On average, it costs \$50 less over 112 days to feed an efficient bull compared to an inefficient one.”*

AGRI-FACTS, July 2006; Agdex 420/11-1

Benefit - Cost Analysis

25-year investment period

❖ 100-cow herd ~ combined cow/calf and feeder steer operation

□ Net present value of surplus income over expenditure : \$17,363

□ Internal rate of return : 42%

□ Annual benefit per cow: \$6.95



Exton et al. 2000

Benefit - Cost Analysis

25-year investment period

❖ 100-cow herd ~ combined cow/calf and feeder steer operation

- ❑ Net present value of surplus income over expenditure : \$17,363
- ❑ Internal rate of return : 42%
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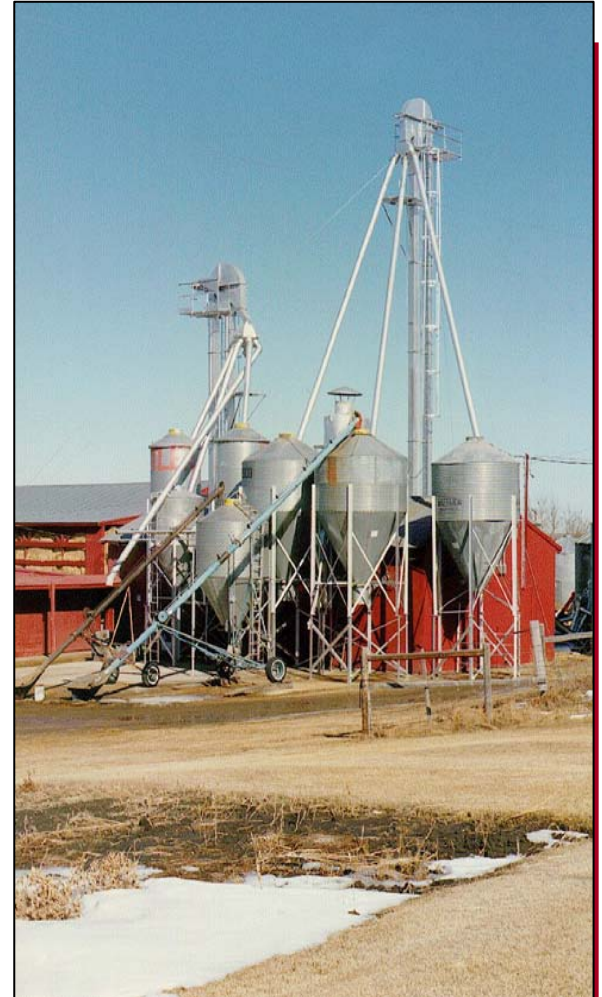


❖ Feedlot sector

- ❑ Savings of \$8.08 per head initially
- ❑ Savings of \$35 per after 25 years

Barriers to adoption

- ❑ High cost of measurement, (-)ve cash flow
- ❑ Sophistication of equipment
- ❑ Lack of appreciation of feed costs
- ❑ Lack of accurate individual animal pasture intake measurement
- ❑ Minimal use of artificial breeding technologies in some species – to spread cost.
- ❑ Practical limitations ~ *Centralized testing (health, management , ...)*



Addressing these barriers

❑ High cost of measurement, (-)ve cash flow

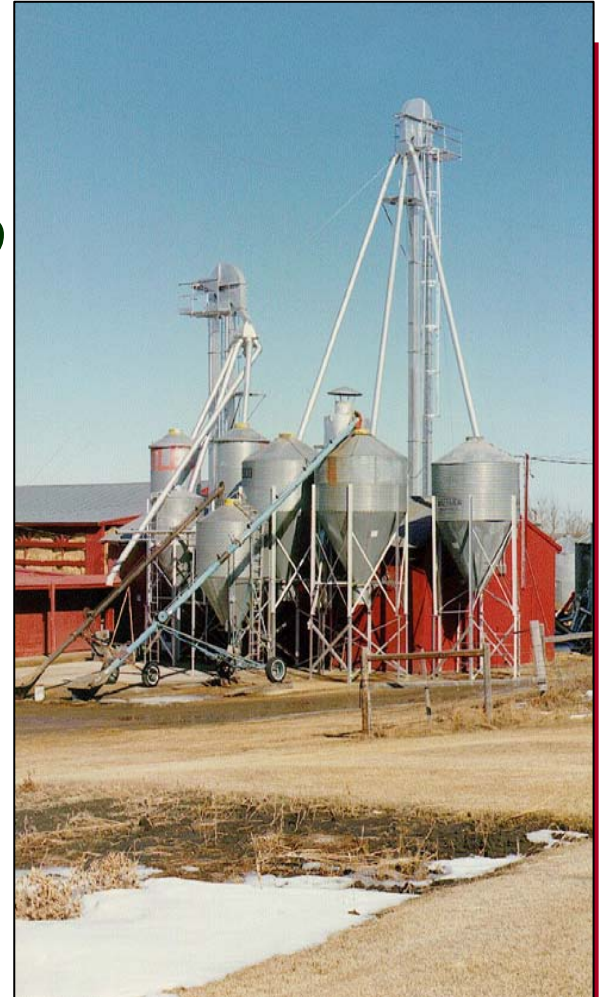
Cost reducing: now \$150AUD; \$70-80CAD

Test 10-20%; Pre-screen – gene markers

Long term investment required, as with any genetic improvement strategy

❑ Sophistication of equipment

GrowSafe _ robust, min maintenance, real-time monitoring



Addressing these barriers

- ❑ Lack of appreciation of feed costs

Improving. Better appreciation in Alberta

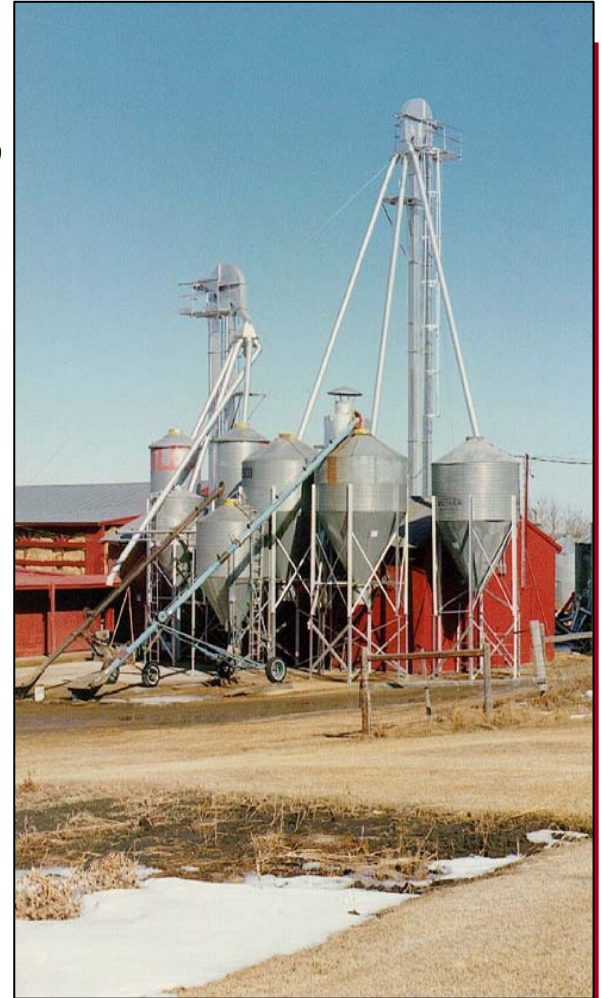
- ❑ Lack of accurate individual animal pasture intake measurement

*Low RFI cattle also efficient on pasture
(Herd et al. 2004)*

- ❑ Minimal use of artificial breeding technologies – to help spread cost

- ❑ Practical limitations

Confidence is building



Summary ~ Industry application

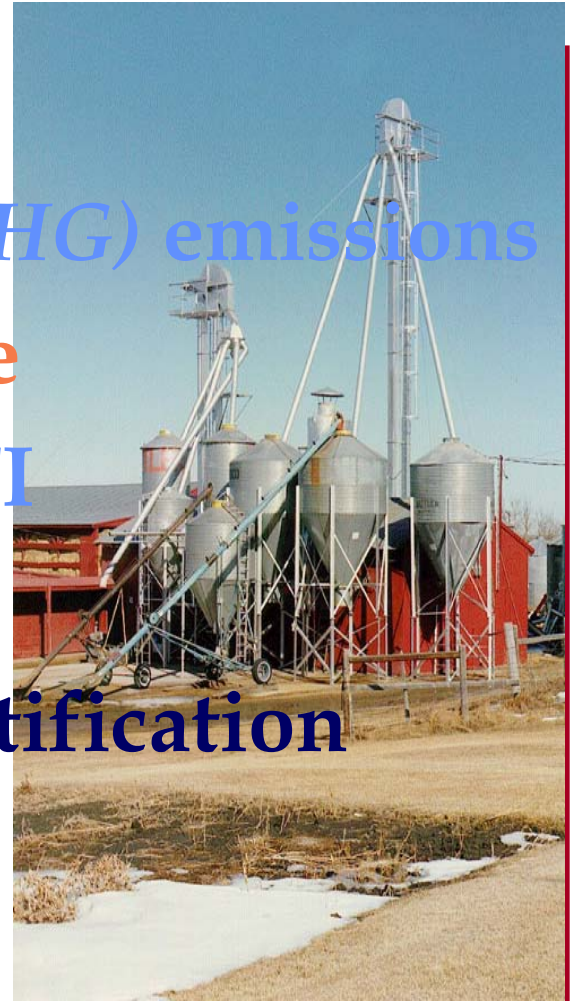
- ❑ Quality standards for RFI testing have been developed and in use in Alberta
- ❑ Facilities and capacity for RFI testing in Alberta are among the best in the world
- ❑ RFI technology already being adopted by the Alberta beef industry ~ over 4,300 cattle tested
- ❑ Selection for RFI is economically beneficial from savings in feed cost
- ❑ A need to lift the rate and level of adoption

Recommendations: Data processing

- ❑ Express feed intake as DM
- ❑ Correct feed to specified ME
- ❑ RFI or RFI_{fat}
- ❑ RFI-P and RFI-F
- ❑ Standard equations for RFI for all tests
- ❑ Use RFI estimated breeding values (EBVs)
- ❑ Centralized RFI database

Outline

- ❑ Residual feed intake (*RFI*)
- ❑ RFI and greenhouse gas (*GHG*) emissions
- ❑ **Conclusions on the science**
- ❑ Industry application of RFI
- ❑ Recommendations
- ❑ Procedures for GHG quantification
- ❑ Protocol specific issues



Procedures for quantification

- ❑ Based on an animal's genetic merit for RFI
- ❑ Estimated breeding values (EBVs) are required
- ❑ EBV set to a baseline year (e.g. 2000) and mean DMI for baseline year noted.
- ❑ **“Certified”** EBVs --- from BLUP, with reasonable level of accuracy
- ❑ **“Assigned”** EBVs --- for progeny, deduced from parental EBVs

Industry sectors: flow of genes

Seedstock breeder

Offers bulls for sale with certified RFI EBVs

Cow-calf manager

Purchases bull with a certified RFI EBV and mates it with some of his cows to produce progeny

Feedlot manager

Purchases steers from cow-calf manager to feed for slaughter

Supermarket

Retail beef as “environment friendly” meat

Estimating reduction in feed intake

□ Pages 40 and 41

Verification

- Animal IDs of RFI test animals need to be linked to CCIA
- RFI test protocols and standards can be readily monitored.
- A centralized database will greatly enhance the auditing of raw data and standardization procedures
- Ways to ensure that standardize BLUP protocols are followed to generate EBVs should be developed
- Ensure that parentage of progeny can be readily verified. Proof of purchase of Low RFI bull/semen may be required

Protocol specific issues

- What level of accuracy of EBVs will be acceptable
- How would protocol-specific EBV standards be maintained
- How will EBVs of imported semen be dealt with
- Can carbon credits be claimed for 2nd generation progeny who have no parental EBVs
- Which sector of the industry claims the carbon credit
- How can the rate and level of adoption be increased

Thanks



Objective of document

□ Objective

To review the state of the science relating to selection for RFI and its association with reduction in GHG emission in beef cattle

□ Scope

Assess the scientific feasibility of selection for RFI in beef cattle, and its link to quantified GHG reductions

□ Purpose

Basis for developing science-based standardized protocols to identify net GHG emission reductions for agricultural carbon offset projects