Residual feed intake (RFI): An indirect approach for reducing GHG emissions.

Basarab, Beauchemin, Baron, Ominski, Guan, Miller and Crowley

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Genetic Selection for Feed Efficiency – Why?

- **Safe, <u>affordable</u>, nutritious and <u>environmentally sustainable</u> beef products** (12-17% of global GHG emissions from ruminant production)

- **Increasing global population (FAO)**
  - ***8 billion by 2030; 9 billion by 2050***
  - ***Global demand for meat is expected to increase by 55%***

  (3 billion people trying to move into the middle class in emerging economies will increase demand for meat)

Past Success

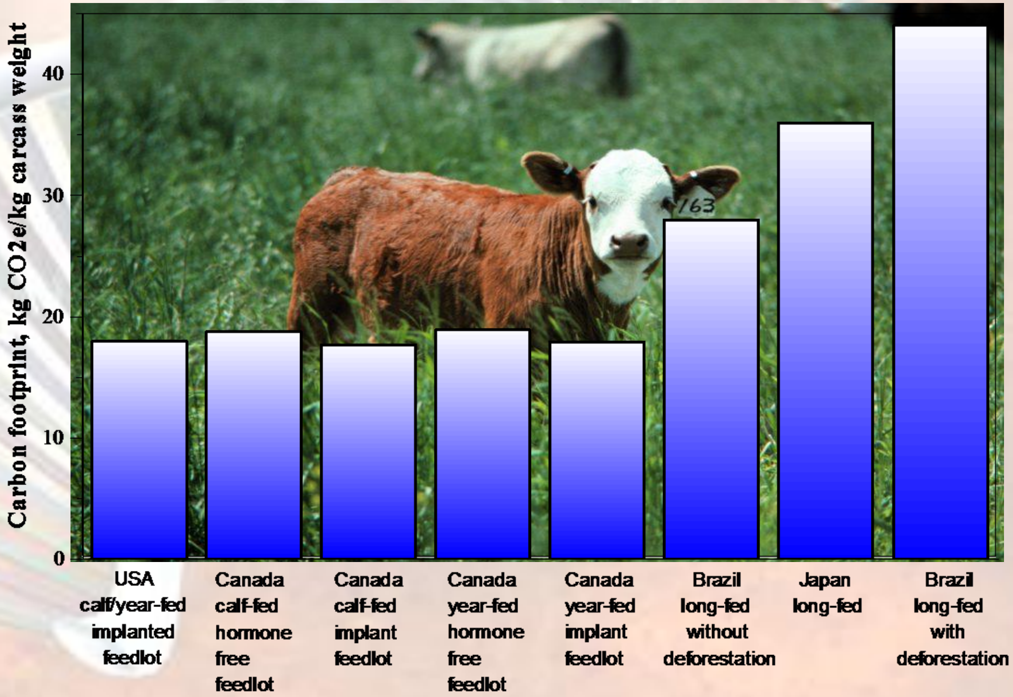
Production Efficiency 1977-2007

Same amount of beef now required

- ***70% of the animals***
- ***81% of the feed***
- ***88% of the water***
- ***67% of the land***
- ***resulting in a 16% decrease in the carbon footprint of beef***

(Capper 2011, Animal Frontiers)

Carbon footprint by region and beef production system (Basarab et al. 2012; Capper 2011)



% Change in greenhouse gas emissions and global warning potential achieved through genetic improvement (1988-2007)

Species	CH_4	NH_3	N_2O	GWP_{100}
Chickens – layers	-30	-36	-29	-25
Chickens – broilers	-20	10	-23	-23
Pigs	-17	-18	-14	-15
Cattle – dairy	-25	-17	-30	-16
Cattle – beef	0	0	0	0
Sheep	-1	0	0	-1

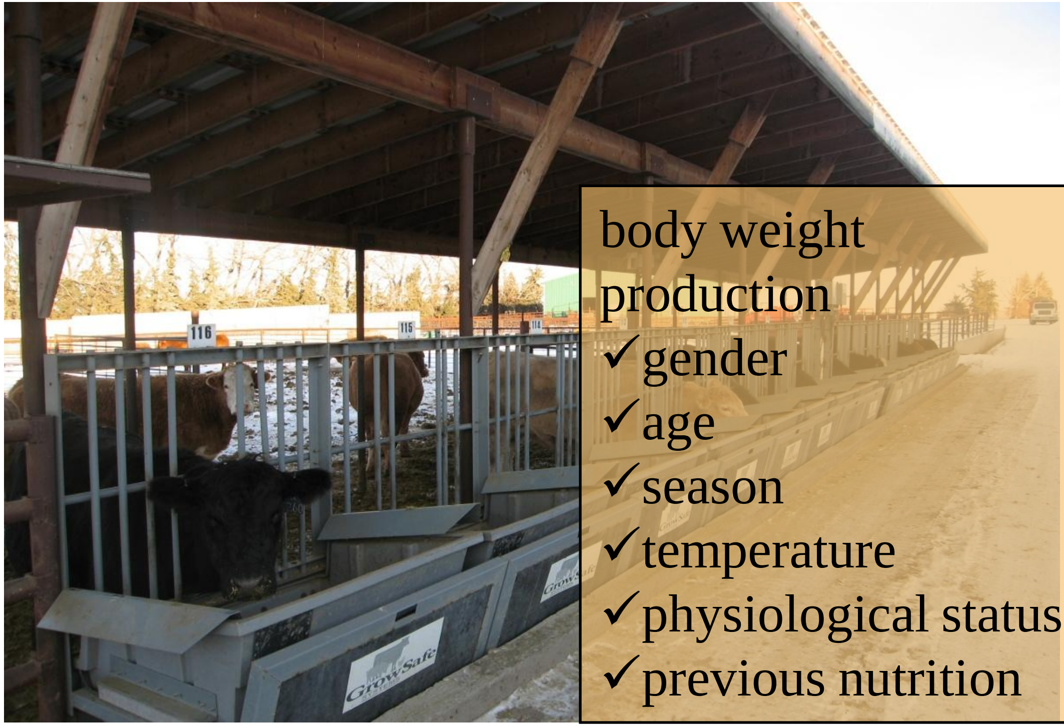
CARBON FOOTPRINT (CO_2e/kg product); Pork 2.8-4.5 kg; Chicken 1.9-2.9; Dairy1.3 kg; **Beef 18-36 kg**

Sources: Project for DEFRA by Genesis Faraday Partnership and Cranfield University (AC0204) from Hume et al. (2011), J. Ag. Sci., doi:10.1017/S0021859610001188 .

Trait criteria for Genetic Selection

- Measurable with at least moderate repeatability
- Heritable
- Few if any adverse genetic correlations
- Economically (socially?) important

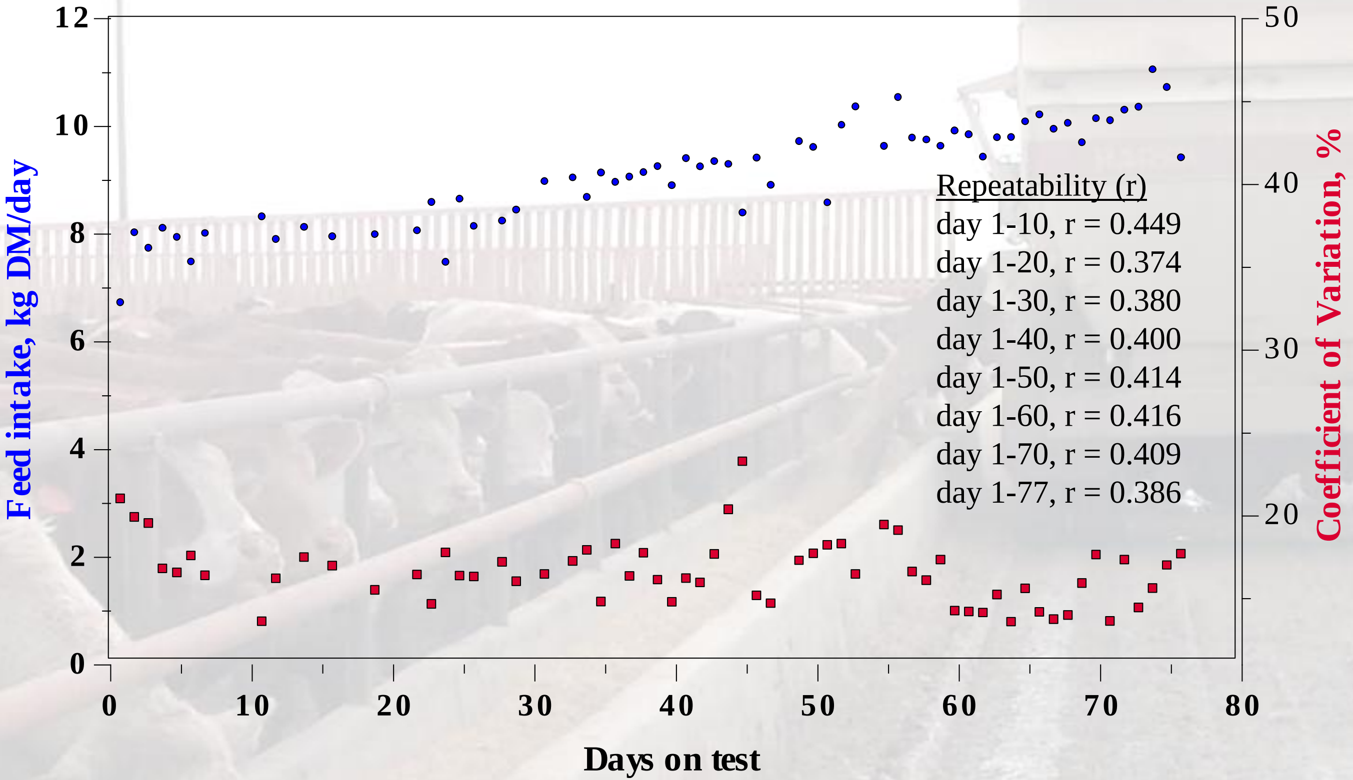
Measurable: Individual Animal Feed Intake Facilities



body weight
production
- ✓ gender
- ✓ age
- ✓ season
- ✓ temperature
- ✓ physiological status
- ✓ previous nutrition

Global GrowSafe capacity: ~68,000 animals; facilities in Canada (8%), US (76%), UK, Brazil, Aus (16%); Sunstrum 2012.

Repeatability (r) of Feed Intake



Feed intake for 99 young bulls fed a growing diet for 77 days
(72.1% barley silage, 24.6% barley grain & 3.3% protein sup., DM basis)

Feeder cattle
r = 0.325-0.407

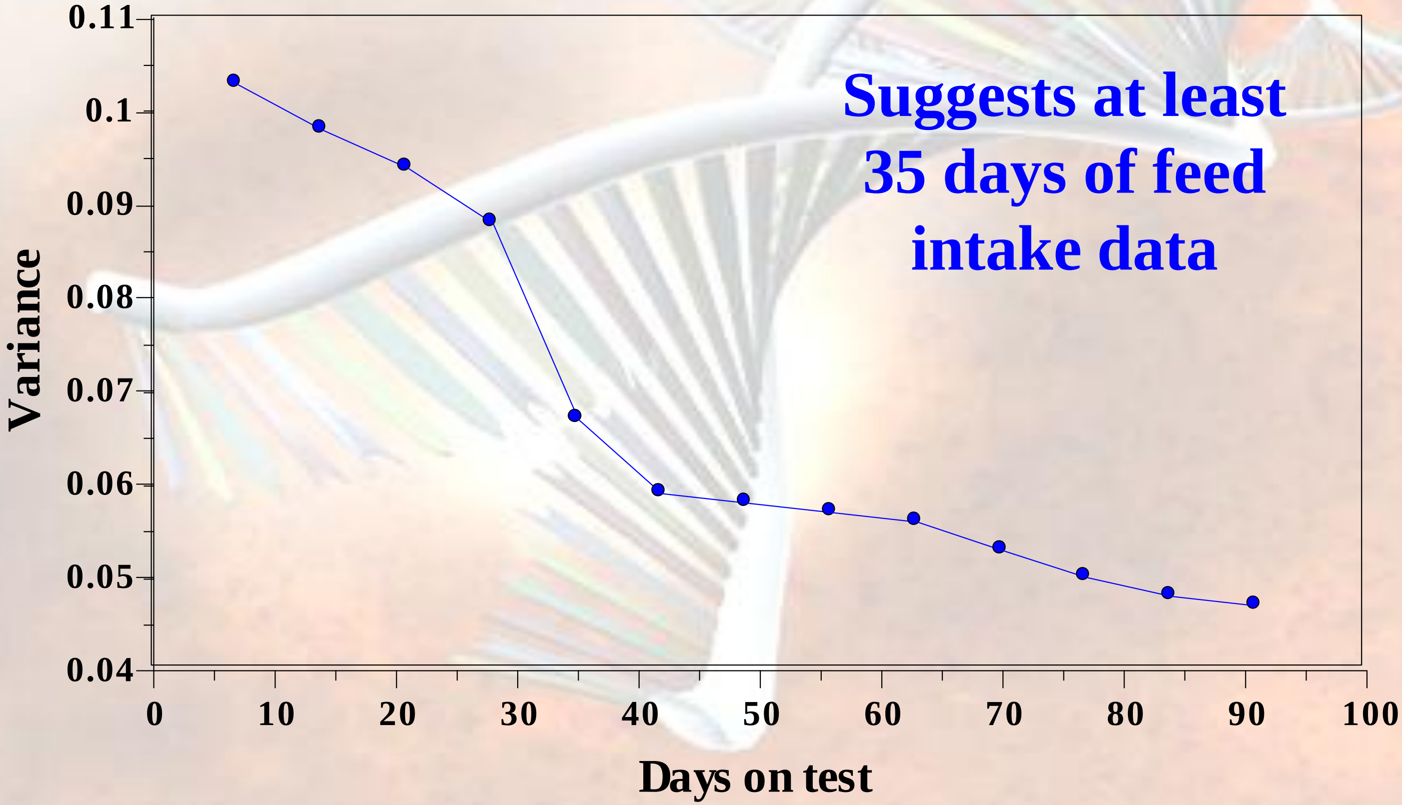
Repl. heifers
r = 0.286-0.380

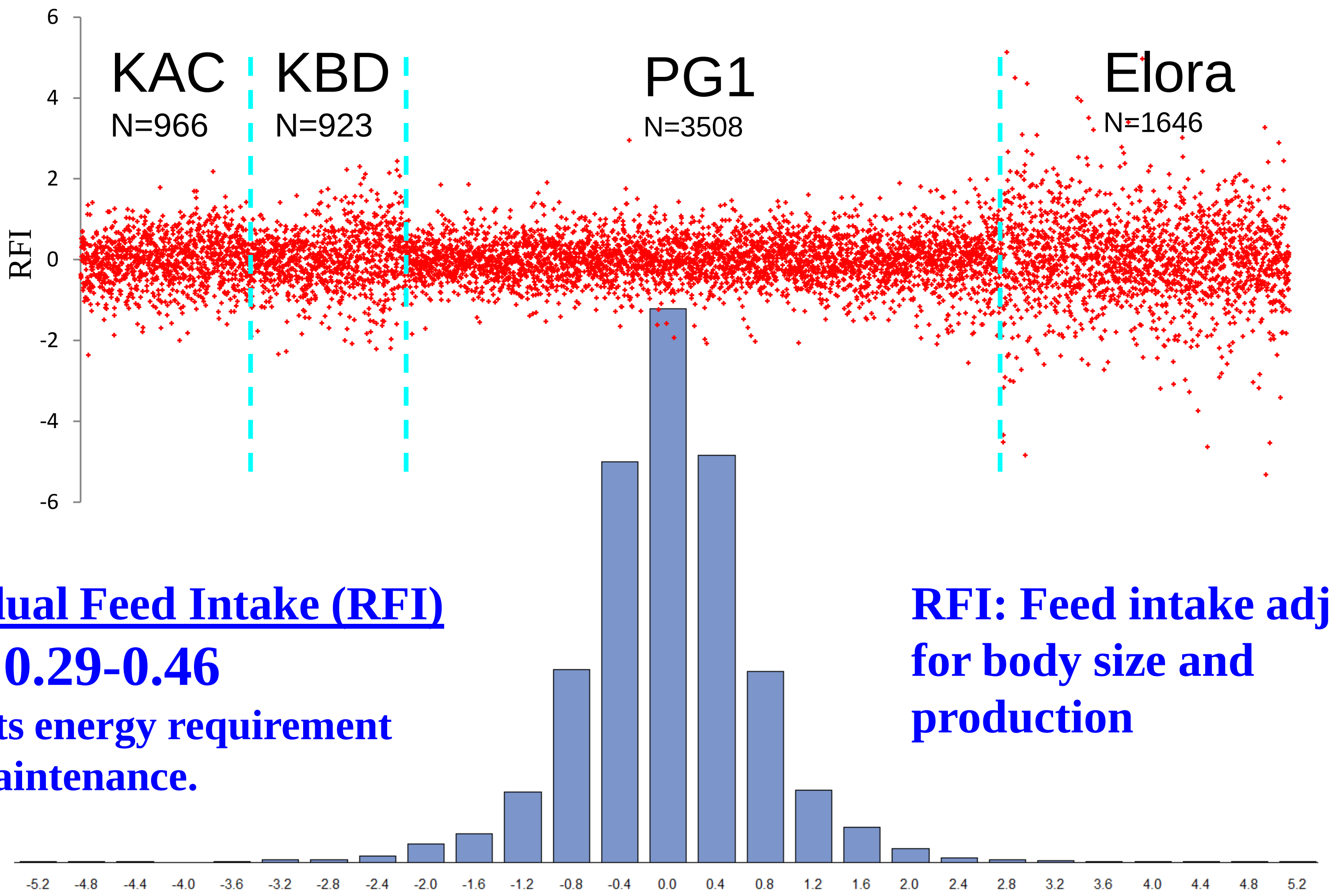
Young bulls
r = 0.374-0.449

Beef cows
r = 0.361-0.491

r = within animal var. / across + within

Effect of days of feed intake data on phenotypic residual variance (adapted from Wang et al. 2006, JAS, 84:2289)





Residual Feed Intake (RFI)

h^2 = 0.29-0.46

reflects energy requirement for maintenance.

RFI: Feed intake adjusted for body size and production

Repeatability of RFI across diets

Grower diet vs. finisher diet, steers and heifers, r_g = 0.45-0.62

example, 75% barley-silage vs. 75% barley grain, as fed basis

Crews et al. 2003; Kelly et al. 2010; Duranna et al. 2011.

Heifers to 1st, 2nd and 3rd parity cows; r_p = 0.2-0.4

(Lawrence 2012)

Conclusion:

High & positive genetic association between RFI-g and RFI-f when cattle are consuming roughage vs. grain, but traits are not biologically equivalent

More importantly, no convincing evidence that bull and heifer RFI would be antagonistic to progeny RFI or feed intake as a cow.

Repeatability of RFI in heifers to cows

Preliminary data, Basarab et al. 2012

Traits	RFI measured as a heifer: High	RFI measured as a heifer: Low
<u>RFI, kg DM/day</u>		
Number of females	12	11
8-12 mo old heifers	0.365	-0.373
4-7 year old cows	0.459	-0.375

Heifers fed 90:10 barley silage:barley grain, free choice

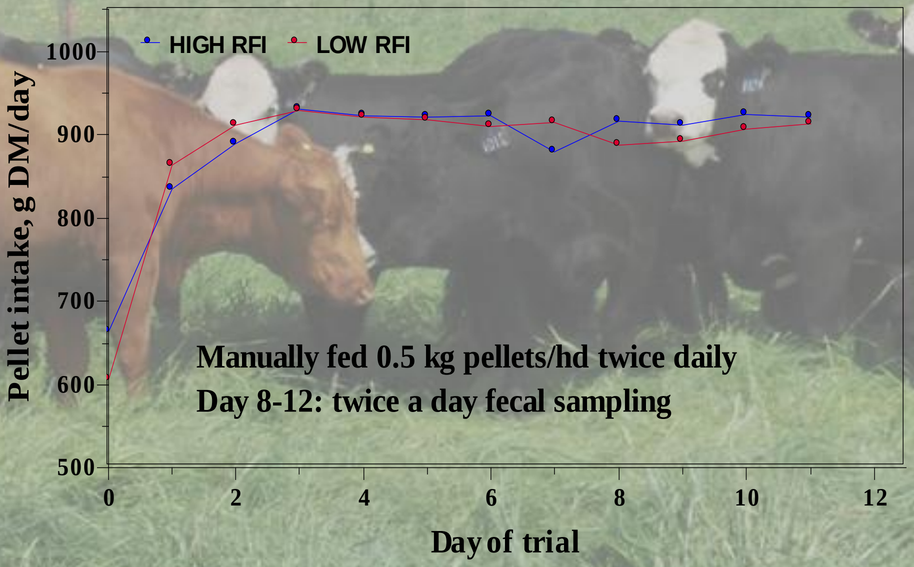
Cows fed 70:30% grass hay:barley straw cube, restricted to gain at 0.25-0.50 kg/day

Feed savings: Heifers: 0.74 kg DM/day x $0.15/kg DM x 365 = $40/heifer/yr

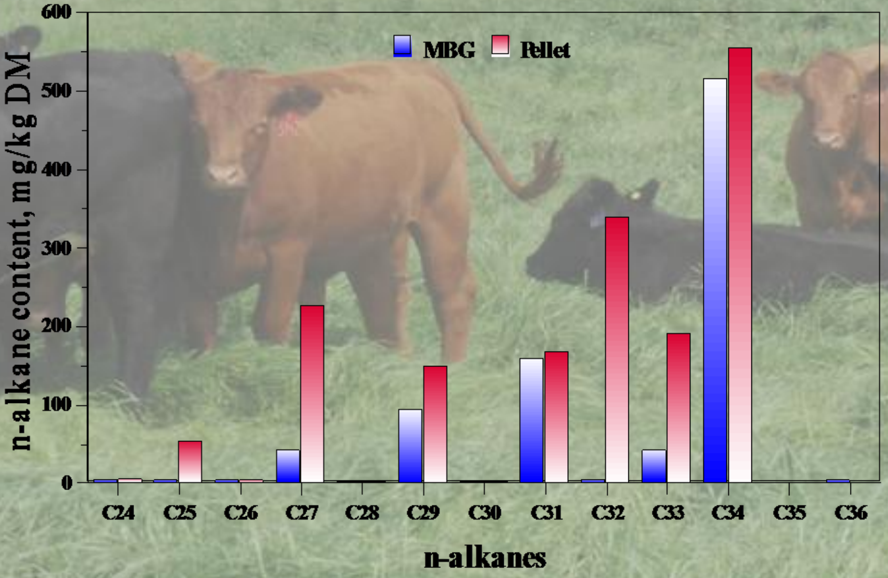
Cows: 0.83 kg DM/day x $0.15/kg DM x 365 = $46/cow/yr

Repeatability of RFI_{fat} during summer grazing

Daily consumption of n-alkane labelled feed pellets during a summer grazing trail

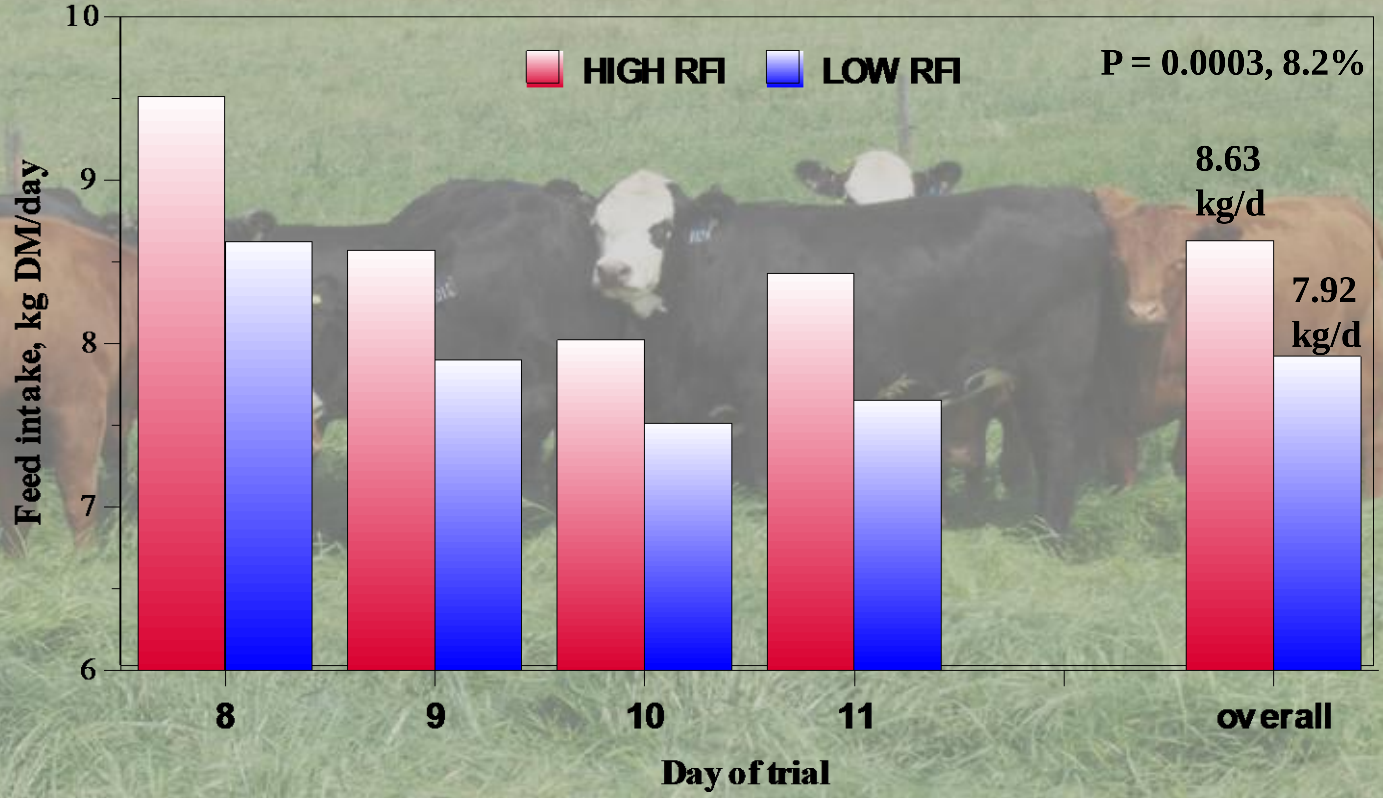


N-alkane profile of meadow brome grass and C32 labelled feed pellets during a 13 day grazing trial



DMI calculated based on forage, supplement and fecal content of C31 and 32, intake of supplement and dose rate of C32 (modified from Boloventa et al. 1994; Moshtaghi-Nia and Wittenberg, 2002)

Feed intake of high and low RFI_{fat} heifers during summer grazing (n=20)

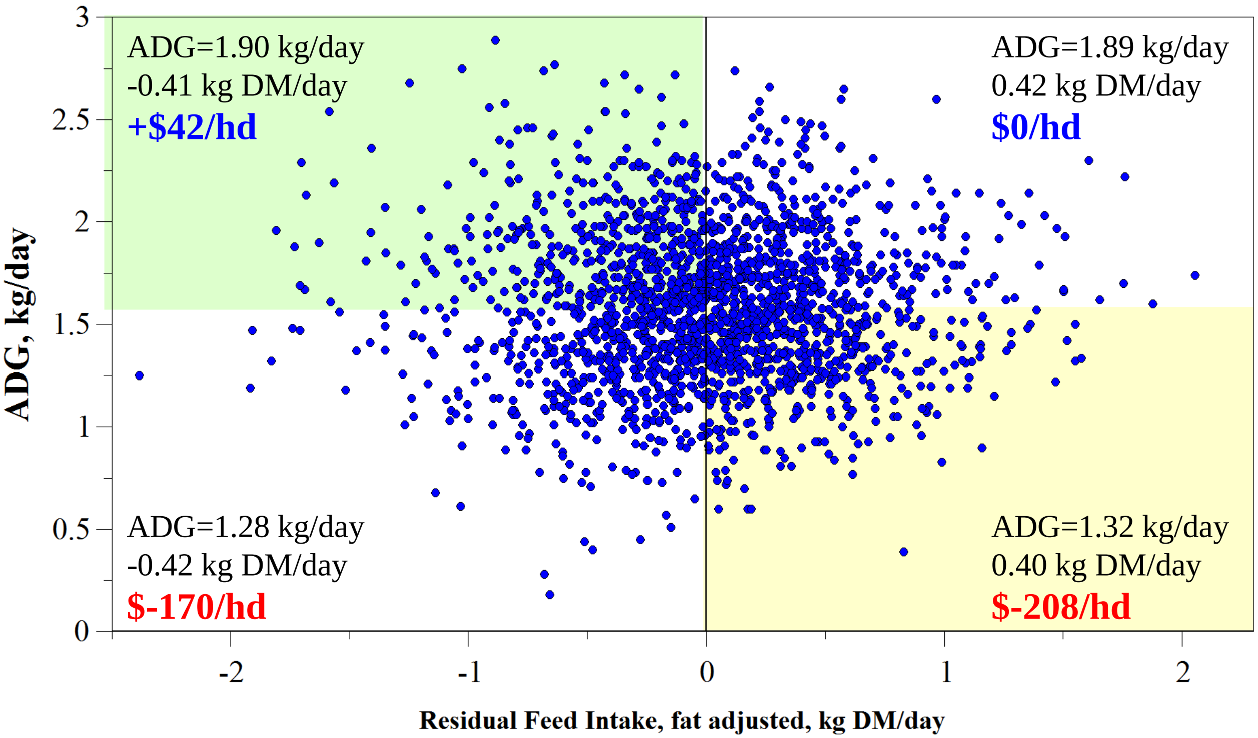


Growth and backfat,
Day 0-46:

HIGH: gain = 32.7 kg
ADG = 0.71 kg/day
BF=0.5
RF=0.7 mm

LOW: gain = 44.9 kg
ADG = 0.98 kg/day
BF=0.9
RF=1.3 mm

Correlation: growth & animal size



Correlations (r_p & r_g) are near zero

N = 2029 feeder heifers and steers

Arthur et al. 2001; Basarab et al. 2003; Crews et al. 2003; Jensen et al. 1992 Basarab et al. 2013

NOTE: Same feeder cost and price, transportation, vet & medicine, interest, yardage, death loss and marketing costs

Correlations: RFI to other traits

Traits	Direction in low RFI	phenotypic correlation	genetic correlation
DMI	lower intake	0.60 to 0.72	0.69 to 0.79
FCR	improved	0.53 to 0.70	0.66 to 0.88
Linear measurements	no affect	-0.08 to 0.15	-------
Feeding behaviours	lower	0.18 to 0.50	0.33 to 0.57
Docility /temperament	no affect	-0.01 to 0.09	0.07
DM & CP digestibility	2-5% improv.	-0.33 to -0.34	--------
Enteric methane	lower	0.35 to 0.44	-------
N & P excretion	lower	0.67 to 0.80	0.38 to 86

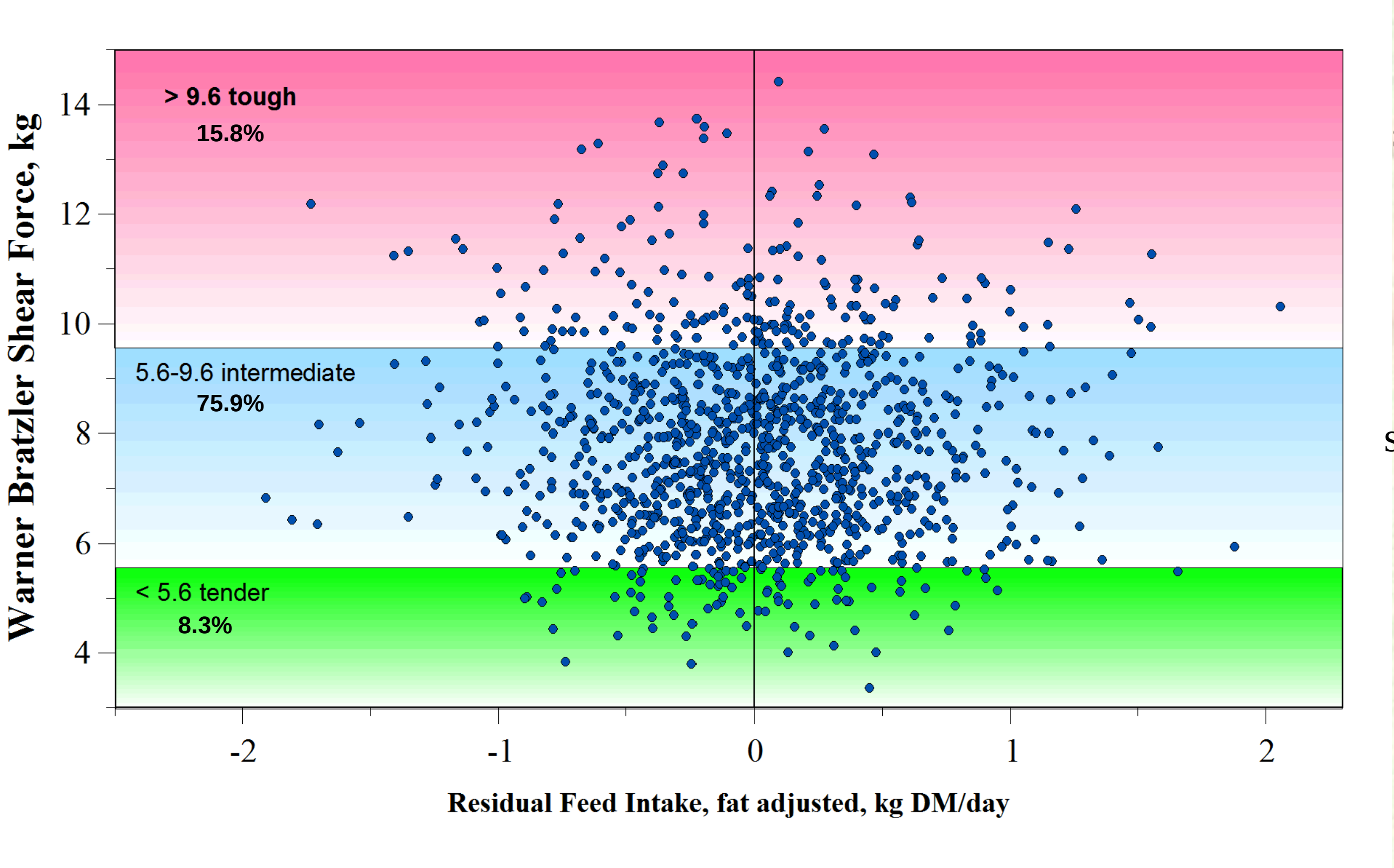
Summary of studies from Australia, Canada, Ireland and USA

Correlations: RFI to other traits

Traits	Direction in low RFI	phenotypic correlation	genetic correlation
Cow productivity	no affect	0.03	------
Age at puberty	3-7 days older	0.00 to -0.16	------
Bull fertility*	slight negative	-0.04 to 0.21	------
5 Carcass traits	2-4% less fat	-0.07 to 0.27	-0.07 to 0.19
34 meat quality traits	no affect	-0.09 to 0.12	-----
WBSF**	little affect	-0.05 to -0.01	-----

Summary of studies from Australia, Canada, Ireland and USA
* sperm morphology and motility;
** may affect tenderness and texture due to decreased lipid and postmortem protein degradation

Relationship between RFIfat and tenderness in striploin steaks aged for 3 days (Basarab & Aalhus, 2013)



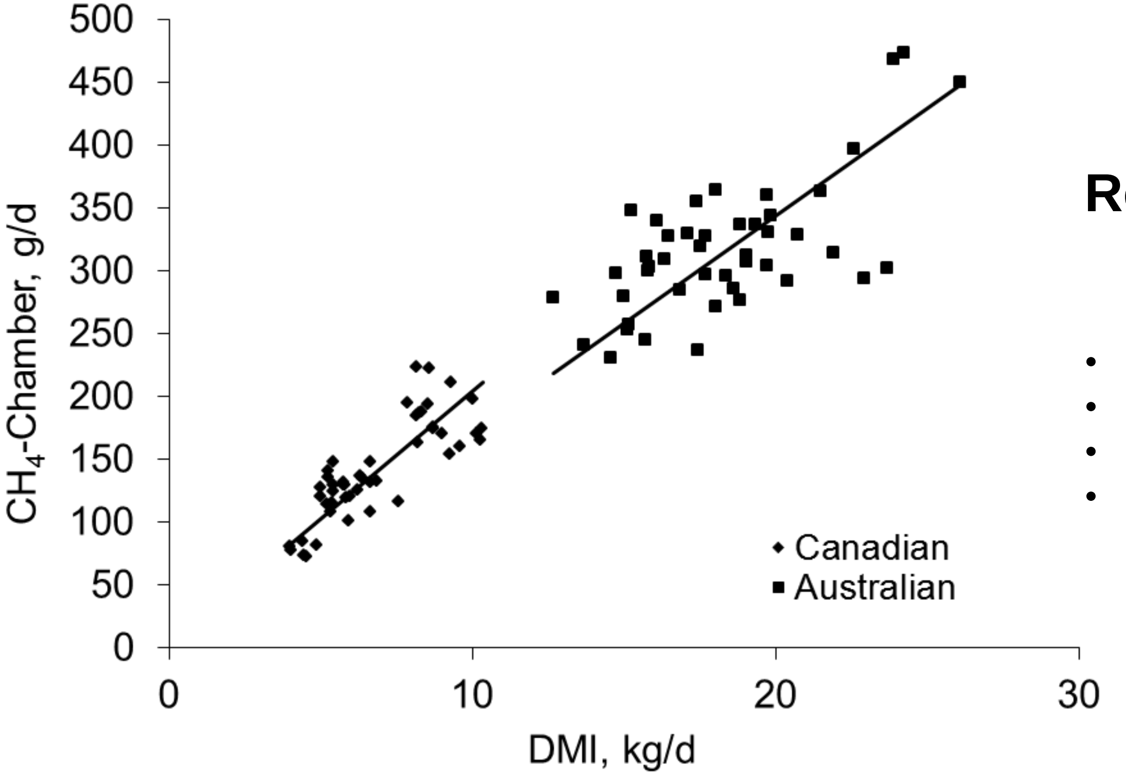
1186 heifers & steers striploins identified by DNA match to post-weaning blood sample

No or low relationship to 34 meat quality, sensory panel and retail quality traits

r_p = -0.09 to 0.12

Three basic hypotheses: low RFI & low CH_4

- **Feed intake driven** - no effect on digestibility or CH_4 yield
- **Feed intake driven** –feed intake affects retention time (RT) and rumen volume (RV); longer RT and higher RV increased CH_4 emissions.
- **Inherent differences** in feeding behaviours, feed intake and RT result in host-mediated differences in microbial communities



Relationship between CH_4 emission and DMI

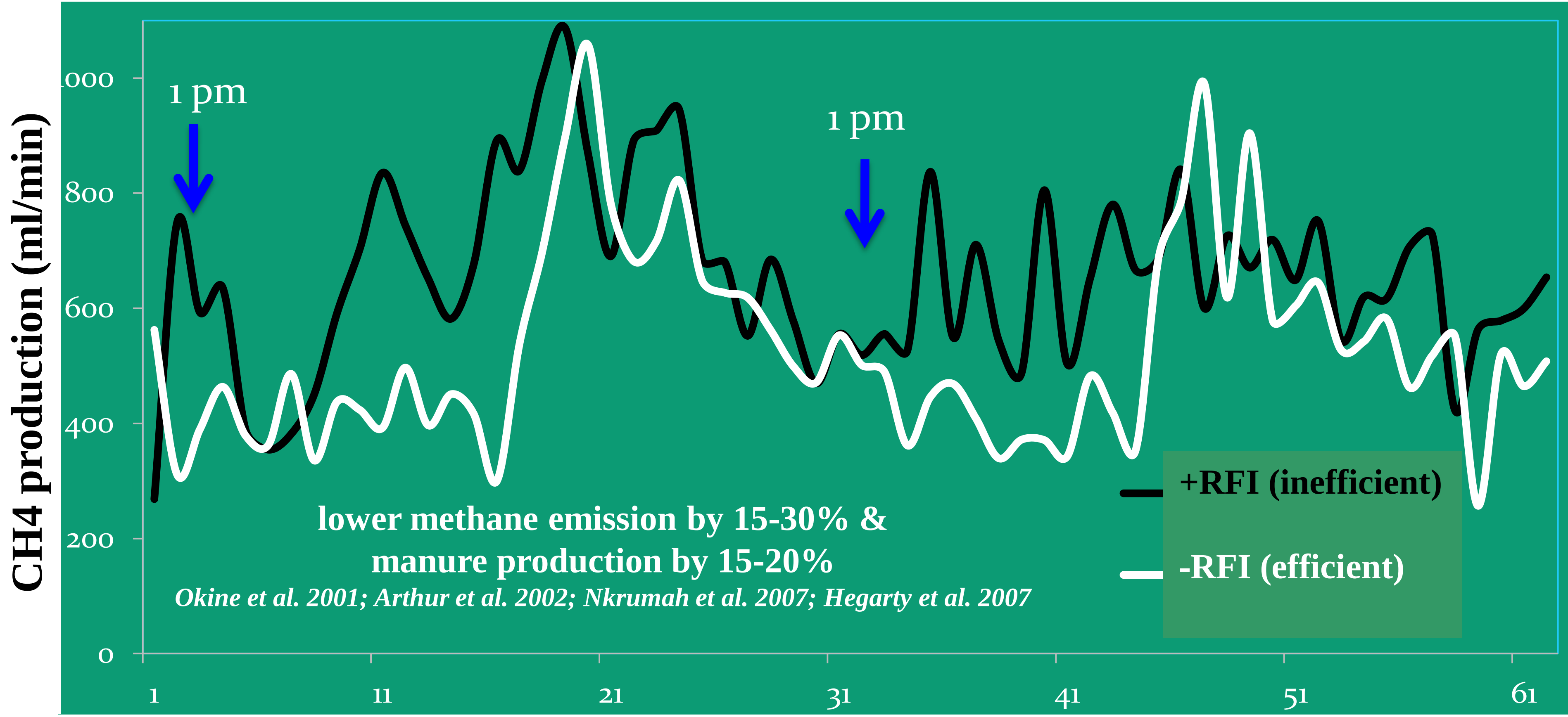
- determined in respiratory chambers
- Australian ($r^2 = 0.454$, P < 0.0001)
- Canadian ($r^2 = 0.677$, $P < 0.0001$)
- Adapted from Grainger et al. (2007), J. Dairy Sci.

IPCC 2006:

CH_4 production rate = ((DMI, kg DM/day *18.45 MJ/kg DM) x (6.5%/100))/0.05565 MJ/g CH_4

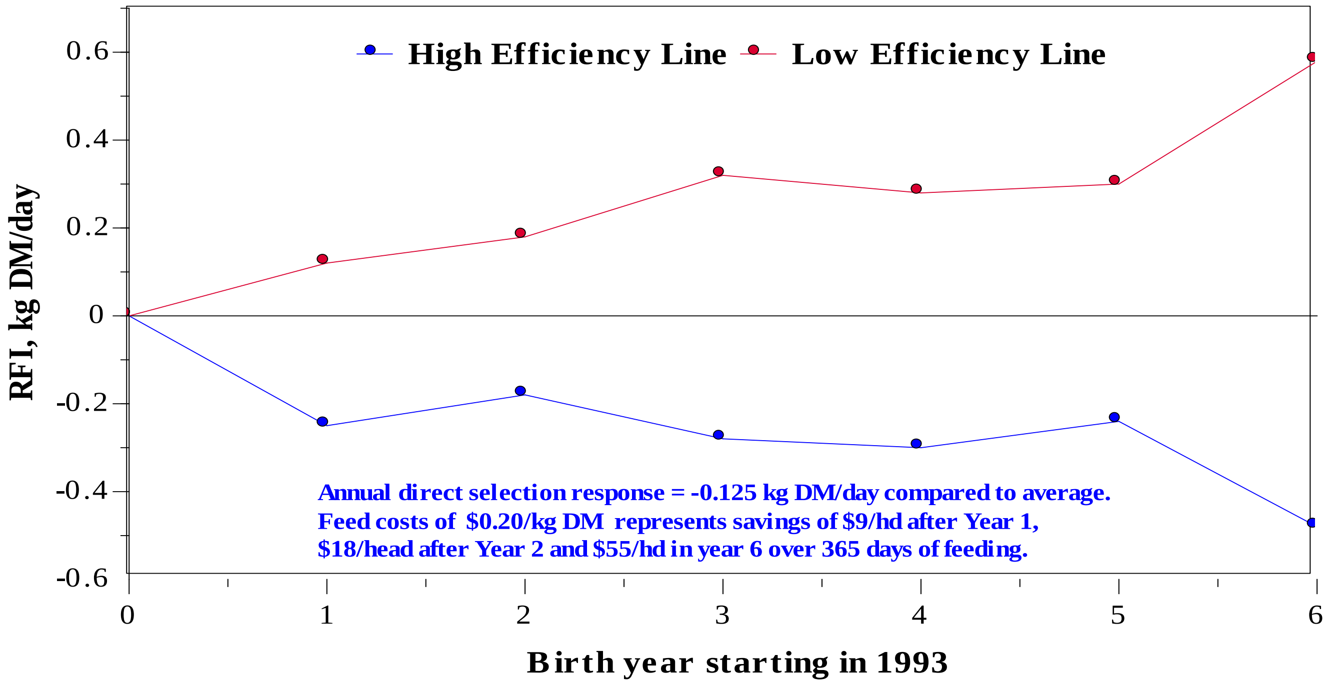
= (10 kg DM/day * 18.45 *0.065)/0.05565 = 215.5 g CH_4/day

Methane production by feed efficiency group
Yuri Montanholi et al. 2011, University of Guelph (n=24)



Trends in estimated breeding values for residual feed intake (RFI) for High and Low feed efficiency selection lines from 1993 to 1999

Trangie Agricultural Research Centre, NSW, Australia. Adapted from Arthur et al. 2001



Annual rate of response =
-0.08 kg DM/day

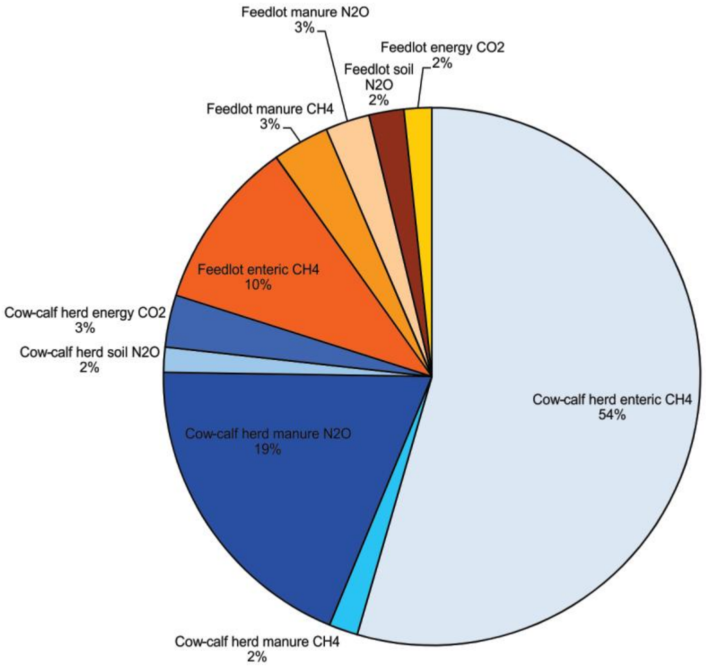
25 year simulation; annual reduction of 568,100 t CO_2e/yr or $8.5 million/yr in carbon credits assuming $15/t.

Effects on manure CH4 and N2O, cropping N2O or energy CO2

Alford et al. (2006)

GHG intensity of a baseline and feed efficient herds after 25 years of selection for low RFI – life cycle assessment

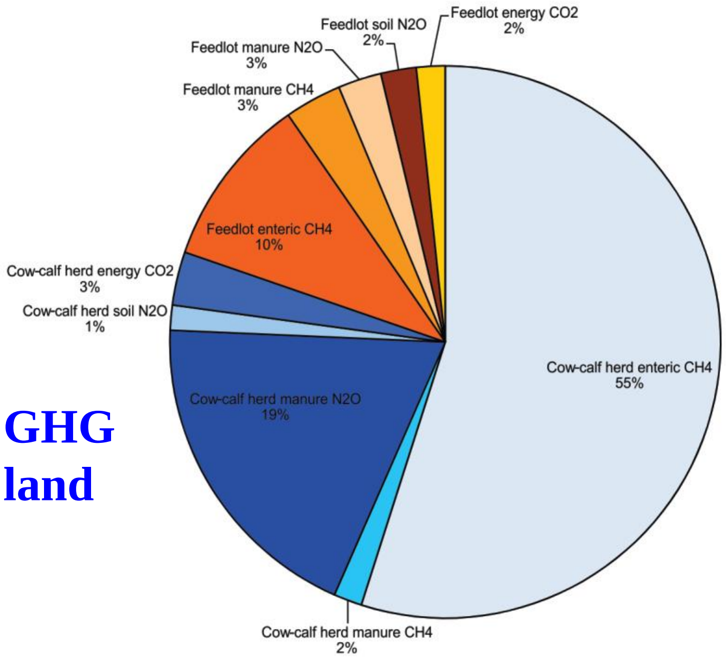
Baseline herd - 120 cows



23.06 kg CO2e/kg carcass beef

14% GHG
13% land

Efficient herd - 120 cows



19.82 kg CO2e/kg carcass beef

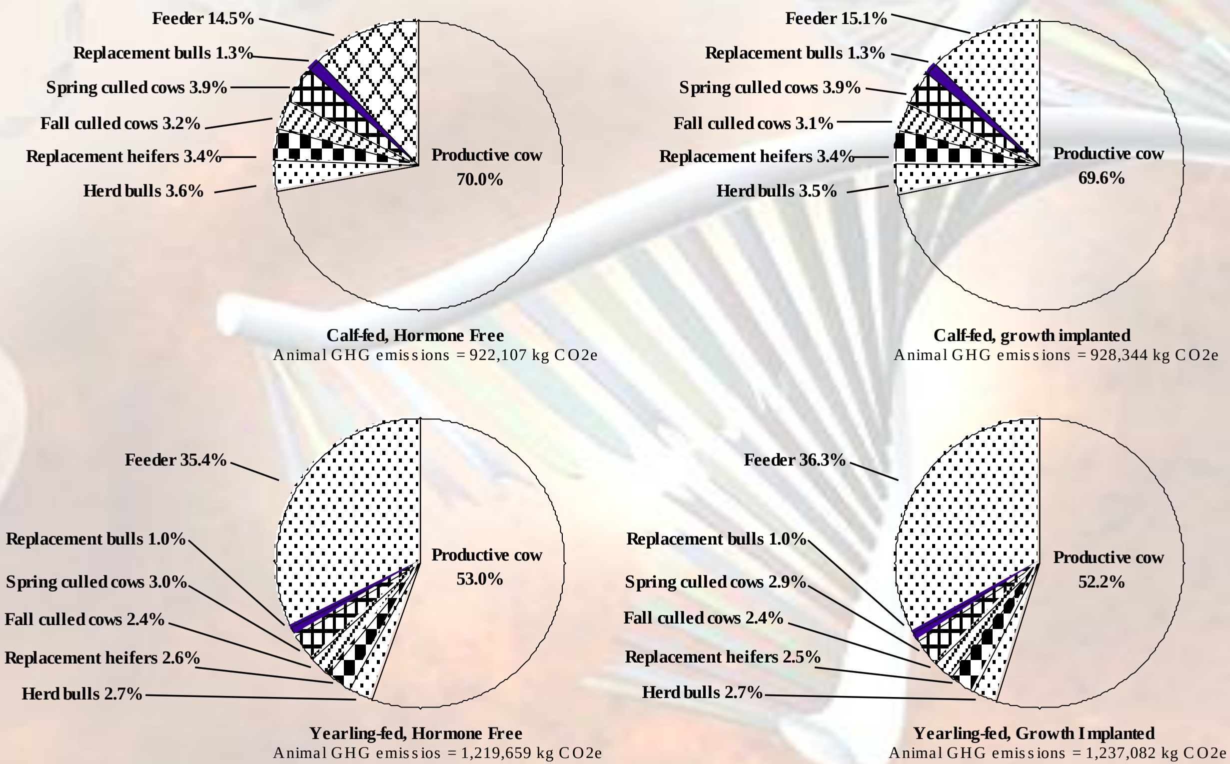
Genetic selection for RFI or its component traits

- improve feed efficiency, with no negative affects on cow productivity
- few antagonistic effects on carcass and meat quality
- small negative affects on age at puberty, but manageable
- reduce enteric methane and GHG emissions

Repeatability of RFI_{fat} during summer grazing

Total GHG emissions four beef production systems

(CO_2 equivalents, 160 cow-herd assumed.



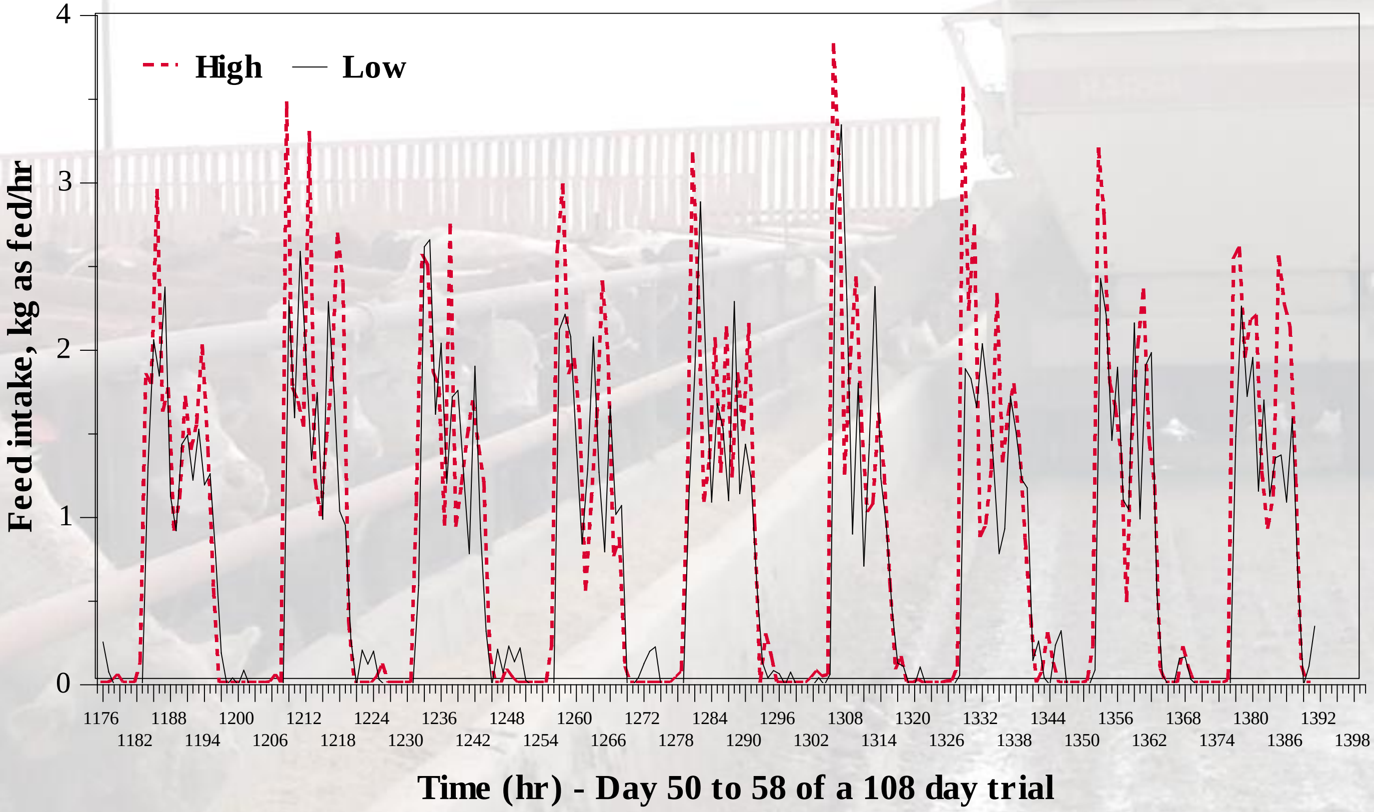
Total GHG emissions include methane from enteric fermentation and manure, nitrous oxide from manure, carbon dioxide from energy use and nitrous oxide from cropping.

CH_4: 12-17% of global GHG emissions from ruminant production

COWS: largest consumer of poor quality forages, low biological efficiency

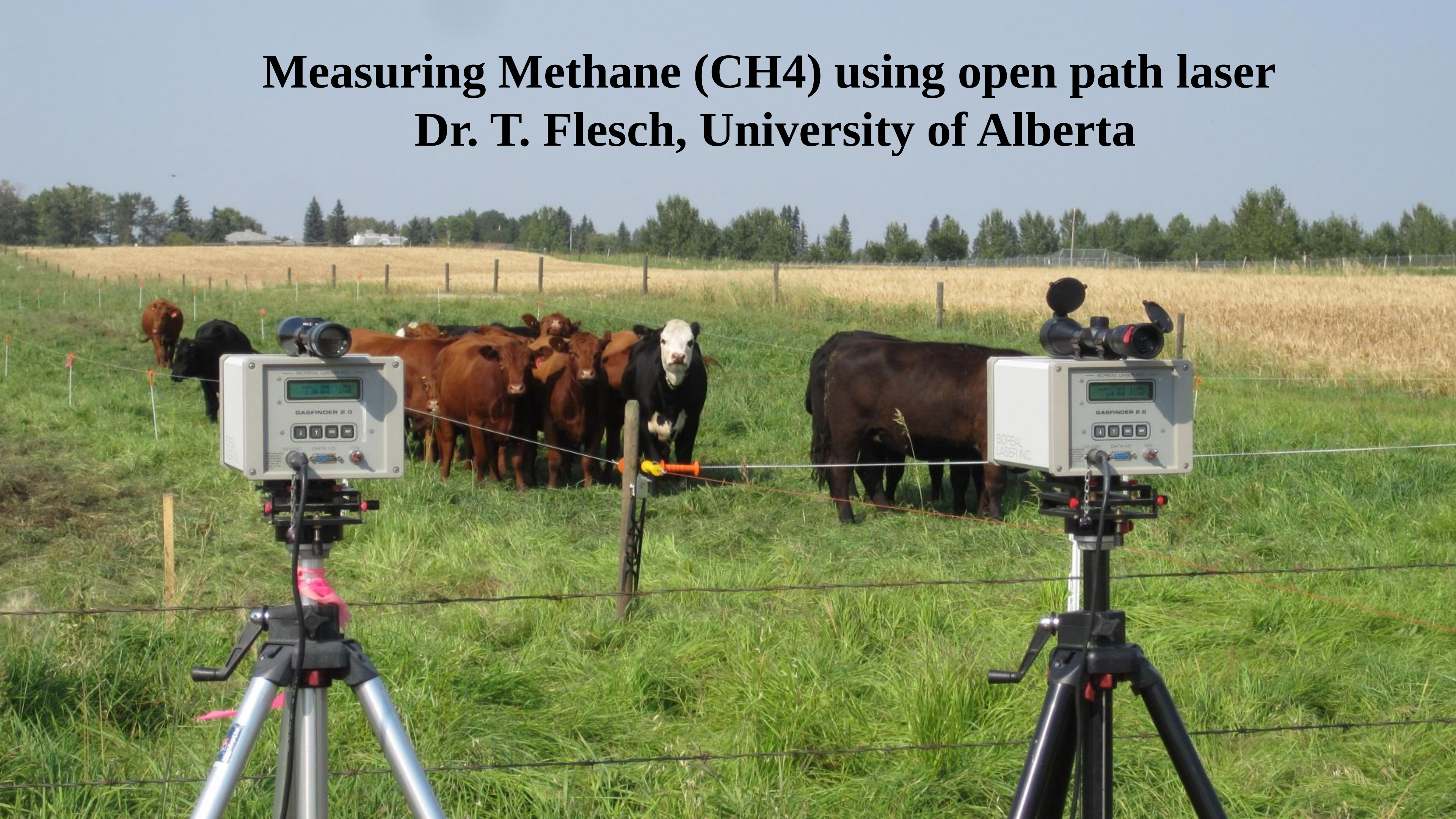
Basarab et al. 2012 *animals 2, 195-220*

Daily feed intake pattern of the 10 highest and 10 lowest heifers for residual feed intake (RFI_{fat})



90%barley silage, 10% barley grain, as fed)

Measuring Methane (CH4) using open path laser
Dr. T. Flesch, University of Alberta



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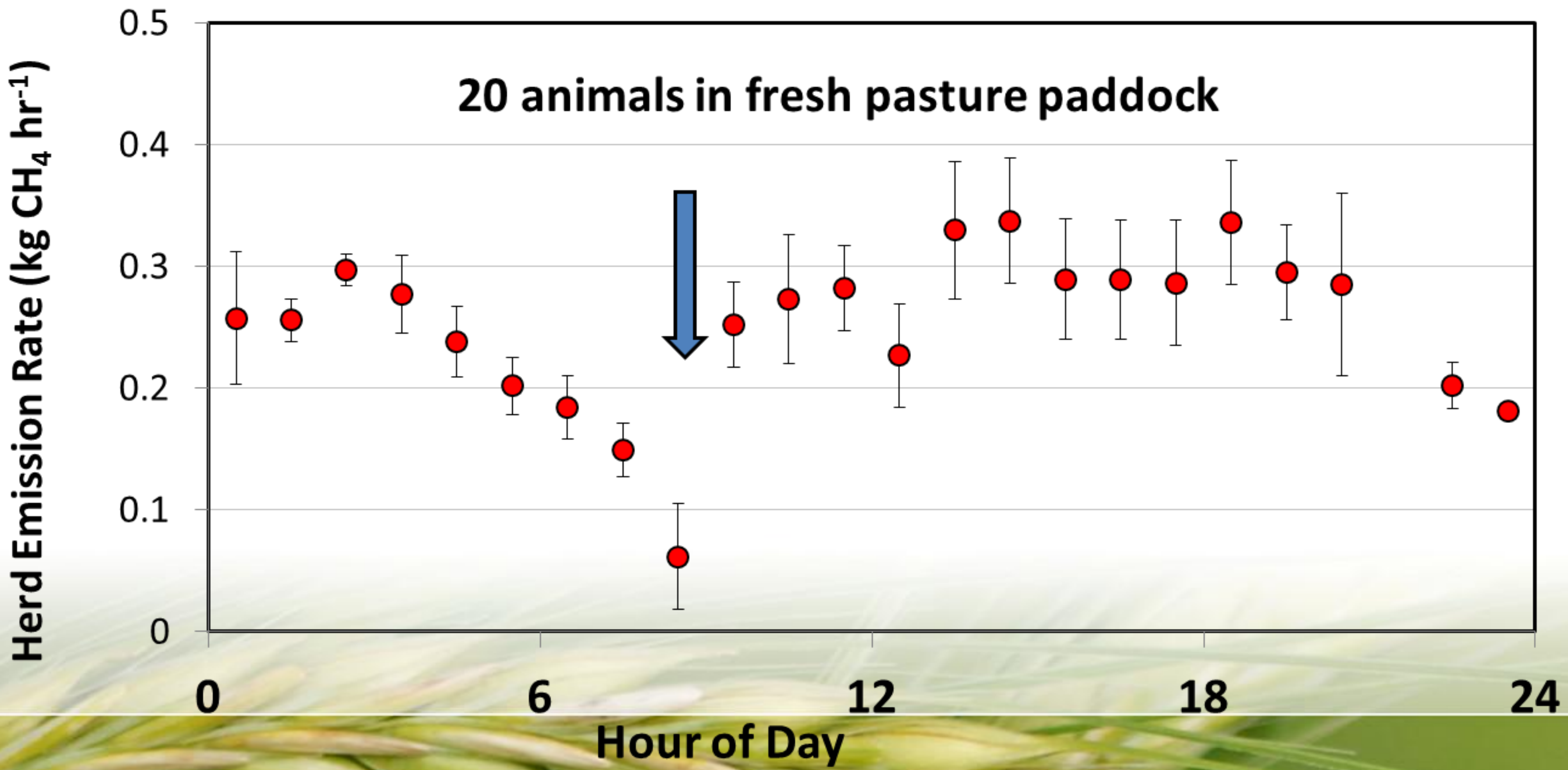

Improve DM digestibility by 2-5%

27 beef steers,
<u>2x maintenance; high grain diet</u>

	-RFI	+RFI
DM dig., %	75.33	70.87
CP dig., %	74.70	69.76

Nkrumah et al. 2006, JAS 84: 2382

16 rumen-cannulated early
<u>lactating Holstein-Friesian heifers</u>

	-RFI	+RFI
DM dig., %	78.5	77.3
CP dig., %	77.2	75.2

Rius et al. 2012, J. Dairy Sci. 95: 2025

Feeding behaviour and feed intake contributes to animals variation in ruminal retention time and digestibility

decrease metabolizability of the diet and increased heat increment of feeding at high levels of intake above maintenance