Making Progress with Feed Efficiency - the case for RFI

(a curriculum developed for cattle producers and animal science students)

Alberta Government

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Foreword

The focus on feed efficiency, through the measurement of residual feed intake (RFI) as an important measure of production efficiency in beef cattle, comes at a time when Western Canadian beef producers are continually being tasked to reduce their production costs to remain competitive. With feed costs representing up to 70 percent of the total costs of production in a beef herd, it's an obvious place to start. However, it seems the low hanging fruit of production efficiencies may be harder and harder to reach and so, as an industry, we need to explore technologies and tools to remain competitive.

The Canadian beef cow herd has been decreasing over the last few years while global demand for meat is rising. Current market trends for beef indicate strong demand and prices which make the industry attractive for those with solid business plans. Those business plans that improve production efficiencies, while at the same time accept changing times and pressures on environmental concerns, animal welfare and social licensing, should consider scientific innovations in breeding, feeding and genomics. RFI is not a single trait to select for, nor is it a silver bullet to improve your herd. What RFI can do for the beef industry is improve our understanding of the relationship between cattle efficiency and profitability—an important concept to dispel the myth that the highest gaining feeders, the cows weaning the heaviest calves or the smaller animals are the most efficient.

An industry focus group was created in 2011 to bring together:

John Basarab, Research Scientist, Alberta Agriculture and Rural Development

Randy Bollum, Cattleman and Seed Stock Producers, R&R Acres, Alberta

Clinton Brons, Director, Business Development, Livestock Gentec

John Crowley, Director of Scientific and Industry Advancement, Canadian Beef Breeds Council

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Kim Ominski, Animal Science Professor, University of Manitoba

Graham Plastow, CEO, Livestock Gentec

Pat Ramsey, Beef Business Development Specialist, Alberta Agriculture and Rural Development

and with the guidance of Raelene Mercer, Charles Young, Lois Hameister and Eugene Balogh, a curriculum was developed. The science had to be transferable in an actionable and understandable way to producers, industry representatives and college students. Many discussions and debates with cattle producers like Jay Cross, Bar Pipe Hereford Ranch, Lee Leachman, Leachman Cattle Company and Cletus Sehn, beef unit manager, Lacombe Agriculture and Agri-Food Canada helped shape the content. Fast forward after some hard work, and the curriculum is being offered across North America.

With support from many organizations and funders, this curriculum represents a comprehensive collection of what is known about feed efficiency from both a practical and scientific approach. As a cattle producer, use the knowledge you gain to improve your production efficiency and product quality while being cognizant of environmental sustainability—a goal you can be proud of.

Susan Markus

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Introduction

Who Should Use This Workbook?

This workbook is for anyone who has an interest in producing beef at a lower cost and reduced environmental footprint, including:

- Beef producers
- Agriculture students
- Industry.

Course Objectives

After completing this workbook, you should be able to:

- Define residual feed intake (RFI)
- Explain why RFI has advantages over the more commonly used feed:gain
- Rank feed efficient cattle using multi-trait selection for use in your own breeding program
- Determine the economic advantages, including potential feed savings, of using genetics to select feed efficient cattle
- Determine the costs to have cattle tested for RFI in an accredited RFI facility.

Content of Course

The course is divided into 10 modules. Some of these modules provide you the theory and background to understand the concept of residual feed intake (RFI). Once you have an understanding of the concept, you are asked to apply the concept to your own operation.

Module 1: Importance of Feed Efficiency

This module introduces you to the concept of residual feed intake (RFI) and how it might have merit as a measure of feed efficiency for your beef operation.

Module 2: Lessons Learned from Other Species

Genetic selection has improved feed efficiency in other livestock species. This module suggests that there are opportunities for beef producers to increase feed efficiency through genetic selection.

Module 3: Genetic Improvement

It is important to understand genetics and its relationship to improved feed efficiency. You are provided with some background information on genetics, heredity and expected progeny differences (EPDs).

Module 4: Evaluate Successful Breeding Plans

In this module you start to apply some of the material to your own operation by developing breeding plan goals for your own herd. You will use minimum culling levels or index rankings to select for several desirable traits. Most importantly, you are able to explain the difference between residual feed intake and feed:gain.

Module 5: Collecting Accurate Data

This module provides you with the guidelines for collecting feed trial data and how you might work with an RFI testing facility.

Module 6: The Value of the RFI Test

You are introduced to the costs and steps to get phenotype testing done. You also learn of the calculations made by those trained in testing.

Module 7: Apply Feed Efficiency Technology in Your Herd

You are now ready to apply feed efficiency technology to your own herd. You will make decisions on traits of importance to you and then make breeding decisions based on multi-trait selection. You will also be able to calculate cost savings and improvements to your herd's feed efficiency baseline as a result of genetic selection decisions.

Module 8: Additional Benefits of RFI

There are additional benefits of RFI, including reduced methane emissions, reduced manure production and reduced requirements for net energy of maintenance.

Module 9: The Future of Feed Efficiency

Research on feed efficiency is ongoing and indicates that the technology will continue to make advances. New technologies measuring feed efficiency are explored.

Module 10: Resource Guide

Use this module to tap into additional resources.

Icons

When you see this icon, you know that you are provided with an example.

When you see this icon, pick up your pen and start applying the information to your own herd.

This icon highlights key points and reminds you to take action.

USB Flash Drive

PC Instructions
Insert USB Flash Drive into computer.
Browse your USB Flash Drive, Double Click on "Click Here to Run"

MAC Instructions
Insert USB Flash Drive into computer.
Browse your USB Flash Drive,
Double Click on "**MAC_users_click_here**" and open folder.
Double Click on "**index.html**"

Glossary

Use the glossary to help you understand the terminology connected to residual feed intake (RFI).

1


Photo courtesy of Spruceville Cattle Company, Alberta

Importance of Feed Efficiency

After completing this module, you will be able to:

- **Compare the economic benefits of feed efficiency to the economic benefits of average daily gain (ADG)**
- **Describe historical and current measures of feed efficiency**
- **Begin to assess how the trait known as residual feed intake (RFI) has merit as a measure of feed efficiency for your operation.**

Introduction

With the world human population expected to increase, the demand for food by 2050 is anticipated to be approximately 70 percent greater than demand in 2010 (FAO 2009). One of the ways to meet the increase in food demand is through an increase in the efficiency of food production for both animals and crops. Not only are increases in feed efficiency critical to feeding the world, they are also a major variable affecting the profitability of livestock production.

Importance of Feed Efficiency

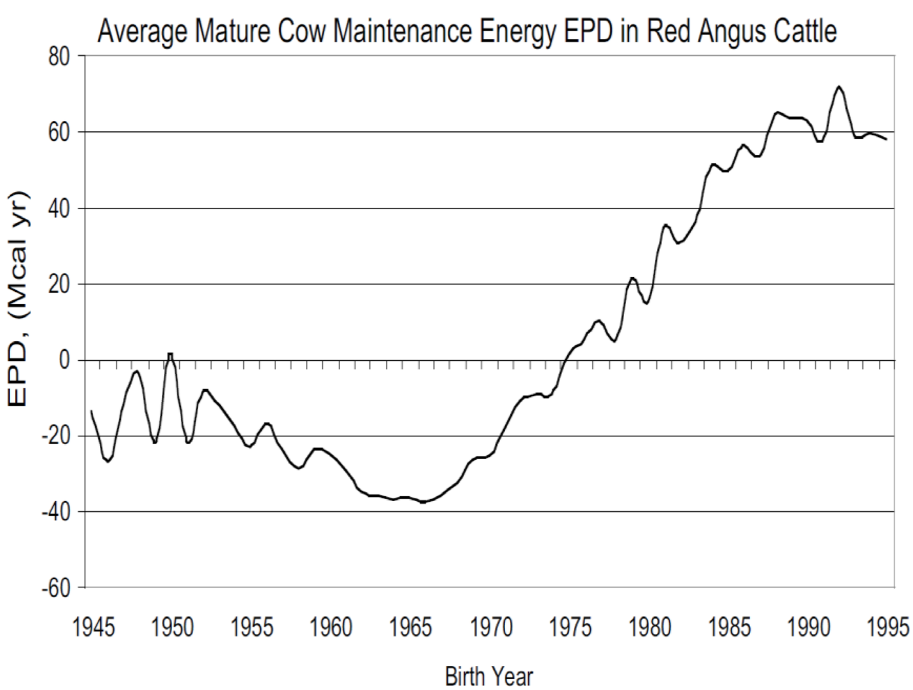
- *Meet increased world food demands*
- *Increase profitability of livestock production.*

Feed efficiency as defined by F:G (feed:gain) or FCR (feed conversion ratio) is not the same as feed efficiency as defined by RFI (residual feed intake). How we make genetic selection and improve beef cattle efficiency needs to include a trait that does not rely on body size and growth.

Benefits of Feed Efficiency Compared to Average Daily Gain

Over the past decades, the size of beef cattle has increased as a result of selecting for cattle that gained the most and had high weaning weights (average daily gain). These larger cattle eat more and ultimately have higher feed intakes and costs of production.

Figure 1.1 Red Angus Cow Size Over 50 Years



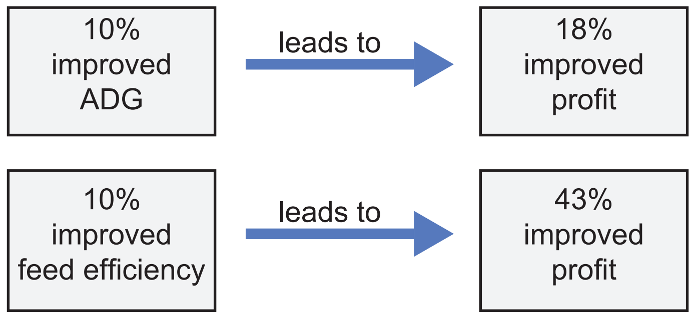
Source: Adapted from Evans et al. 2002

The graph shows how expected progeny differences (EPD), which can be defined as the best estimate of the average differences we would expect to see in individual animals, have increased over the years.

Now compare the benefits of average daily gain to the benefits of feed efficiency.

- The economic benefits of a 5 percent improvement in feed efficiency may be approximately four times greater than a 5 percent improvement in average daily gain in a beef production system (Gibb and McAllister 1999).
- Studies using cattle in the feedlot have demonstrated that a 10 percent improvement in average daily gain (ADG) improved profitability by about 18 percent, whereas a 10 percent improvement in feed efficiency returned a 43 percent increase in profits (Fox et al. 2001).

Improving feed efficiency leads to much greater profit than improving ADG.



What this means is that feed efficiency considers both input (feed consumed) and output (gain) whereas ADG only considers gain without considering the inputs required to achieve that gain. Reducing production costs or increasing feed efficiency is very important to improve the production efficiency and profitability of the livestock industry. Furthermore, using genetics to improve the feed efficiency of cattle is a way to make permanent and cumulative progress in animal production. The alternative is to rely on management and production factors that vary from year to year.

Measures of Feed Efficiency

Feed efficiency has been defined in many different ways. Since the 1950s, numerous alternative feed efficiency calculations and definitions have been proposed making it difficult to come to a common understanding of what the term "feed efficiency" means. The aim of this section is to provide you with an understanding of the historical and current measures of feed efficiency.

> Note: Most of the measures of efficiency such as maintenance efficiency, partial efficiency of growth, cow calf efficiency, relative growth rate and the Kleiber ratio all have a more academic use and are related to body size, growth and composition of gain and are, therefore, given less emphasis in this resource. These measures are described briefly at the end of this module.

The two most applicable measures of feed efficiency for the beef industry today are feed conversion ratio (FCR) and residual feed intake (RFI).

Gross Feed Efficiency or Feed Conversion Ratio (FCR)

Feed conversion ratio is the ratio of input (feed intake) to output (weight gain) over a certain defined time period. Selection based on FCR leads to increases in the efficiency in beef production during the growth and finishing phases and, therefore, is very beneficial to the feedlot industry.

As you learned in the previous section, there are key advantages of feed efficiency over average daily gain. However, FCR is well known to be genetically and phenotypically (includes the effects of genetics and environment) correlated with measures of growth, mature body weight and level of production. Thus, selection of animals based on these measures would result in increased mature body size and hence increase in maintenance requirements (Crews 2005), with a consequent increase in feed intake and cost of feeding. To overcome this problem of increased feed intake, you can better manage your herd by paying attention to the following factors.

Factors That Affect Feed Conversion Ratio

- Genetics: certain pedigrees are more feed efficient than others; increased inbreeding makes feed:gain poorer.
- Sex: males generally have improved feed:gain over females.
- Age: younger animals generally have improved feed:gain compared to older animals.
- Age of Dam: progeny from dams between the ages of 5 to 8 years of age generally have better feed:gain than progeny from younger or older dams.
- Environment: shelter from wind, rain and snow generally improves feed:gain.
- Mud: excess mud in pens makes feed:gain poorer; bedding for cattle improves feed:gain.
- Seasonality: generally, Canadian spring feeding situations have improved feed:gain compared to summer and fall feeding seasons.
- Stress: high stress situations for cattle result in poorer feed:gain.
- Parasites: an increase of internal parasites, flies and ticks makes feed:gain poorer.
- Grain in the Ration: higher levels of grain and concentrates in the ration, over 85 percent, generally improve feed:gain.

If you are a feedlot or backgrounding producer, addressing these factors will help you to improve the efficiency of your management system.

If you are a seedstock and cow/calf producer, use your understanding of genetics and its relationship to feed efficiency for your management system.

- Ionophores: inclusion of products with the active ingredient monensin or lasalocid or salinomycin sodium into the feed ration generally improves feed:gain.
- Stocking Density: too many or too few animals per pen generally makes feed:gain poorer.

Cost Savings with Feed Efficiency

Feed intake varies significantly in any group of cattle.

Example **Comparison of Steers with Different RFI**

If a pen of 100 calves weighing 1000 lb. has an average individual intake of 25 lb. of feed, the expected range in individual feed intake would be 20 to 30 lb. with no difference among gain in the calves. If estimated feed costs were $160 per ton with 300 lb. of gain in the feedlot, the average feed costs would be $278 per head. The most efficient calf in the pen would only consume $223 of feed, $55 less than the pen average.

Comparison of Steers with Divergent RFI

If you select for average daily gain and feed:gain, you cannot make genetic progress in feed efficiency.

Performance data during a 77-day growing trial:

538 lb.	Initial body weight	535 lb.
2.11 lb./d	ADG	2.16 lb./d
1502 lb.	Expected feed intake	1509 lb.
1717 lb.	Actual feed intake	1232 lb.
+215 lb.	Residual feed intake	-277 lb.

The more efficient steer (negative RFI) gained the same but ate 485 lb. less feed than the less efficient steer (positive RFI).

G.E. Carstens, bif 2006.

RFI, explained in detail on page 1-9, is the difference between what an animal is expected to eat and what it actually eats.

The lesson from the previous example is this. If you don't know which calf is most efficient, you can't select for its genetics, and that's why selecting for average daily gain (ADG) and feed:gain don't allow you to make genetic progress in feed efficiency.

Table 1.1 Comparative Costs and Savings shows that a 5 percent increase in daily gain is not more profitable compared to a 5 percent increase in feed efficiency even though animals with increased ADG were on feed for 9 days less. For a 5 percent increase in daily gain to be more profitable, steers had to be fed for 200 days and gain 326 kg giving extra gross revenue of $29.60 (15.5 kg of beef @ $1.91/kg). The net margin would be $12 since it cost an extra $17 to feed the steers for the extra 9 days. The goal of many producers to increase growth rate (increase average daily gain) in cattle is based on the assumption that there is a dilution effect of maintenance feed energy intake over a faster rate of growth due to the animal being a physiologically lower age (younger) at a fixed slaughter weight (Luiting et al. 1994).

Table 1.1 Comparative Costs and Savings (5% Increase in Feed Efficiency vs 5% Increase in Average Daily Gain in Steers)

	Baseline over 200 days	Calculated 5% Increase in Feed Efficiency (200 days)	Calculated 5% Increase in Weight Gain (191 days)
Feed Intake	9.45	8.98	9.91
Feed Efficiency (kg/kg gain)	6.08	5.78	6.08
Gain (kg/day)	1.55	1.55	1.63
Feed ($/kg gain)	1.13	1.07	1.13
Feed Cost ($ for total gain/day)	1.75	1.66	1.84
Total Feed Costs	$350	$332	$352
Total Costs Including Yardage (@ 37 cents/day)	$424	$406	$422
Savings for 200 days @ $0.186/kg feed)	-	$18 per head	$2 per head

Source: Adapted from Luiting et al. 1994

The data in the above table indicates that selecting for a faster growth rate leads to a higher efficiency only as a result of a lower degree of maturity at slaughter. What has ended up happening in the beef industry is that, to be economically viable, the slaughter weights have had to increase.

Example **Growth Rates of Large Frame Cattle**

In the past, for large frame size animals, cattle were not expected to produce 13 mm of subcutaneous fat at the 12th rib until their weights exceeded 544 kg for steers and 454 kg for heifers. However, for modern large frame cattle, the weights at which they are expected to produce 13 mm of fat at the 12th rib have increased to 612 kg for steers and 544 kg for heifers (Basarab 1996).

This shows how the beef industry has been selecting for ADG and animals are getting larger at younger ages.

"Ultimately, selection for higher growth rates, using FCR, has lead to a population of cattle with increased maintenance requirements, higher feed requirements and intake with subsequent higher feed and environment costs. Selection for animals based on their feed efficiency has to take place with a measure that is independent of body weight to avoid this problem. That measure is RFI."

Dr. John Basarab

For more information on these measures of feed efficiency, see Module 10 Resource Guide.

Other Measures of Feed Efficiency

As indicated in the previous section, the following measures of feed efficiency do not have a practical use in the cattle industry. They are briefly described below to give you an indication of the types of research on feed efficiency and some of the limitations of the following measures.

Maintenance Efficiency

Maintenance energy can be defined in growing animals, for example, as the ratio of body weight (BW) to feed intake at zero BW change (Archer et al. 1999). The interest in maintenance efficiency derives from reports that maintenance energy requirements may account for 65 to 70 percent of total beef production energy requirements, making it a very important component in determining production efficiency and profitability. The problem, however, is that maintenance efficiency is an input to output ratio trait, and that means that changes in either of the components of that ratio could result in a disproportionate amount of selection pressure being placed on that component with the highest genetic variation. In addition, changes in ratio traits do not necessarily translate to equivalent improvement in efficiency because the genetic trends that can result from selection on either the numerator or denominator of a ratio are somewhat independent of one another.

Partial Efficiency of Growth (PEG)

Partial efficiency of growth (PEG) is defined as the weight gain per feed intake less the maintenance requirements of the animal (Archer et al. 1999). Although PEG has been reported to be highly correlated with feed intake and other measures of efficiency such as FCR and residual feed intake (Nkrumah et al. 2006), it suffers from the same deficiencies as noted for FCR and maintenance efficiency.

Cow-Calf Efficiency

Cow-calf efficiency is defined as weight of calf weaned per unit of feed intake by the cow and its progeny, over a production cycle. While the index may have merit for the cow-calf industry as it relates to the mature cow herd, it has proven to be difficult to implement in practice because the calculation requires considerable effort and expenditure to collect intake data. In addition, the contribution of genes from the sire does confound the genetic merits of using the cow-calf efficiency as an index of efficiency in the cow-calf industry. Also, this index suffers from the same disadvantages as the ratio indices such as FCR and maintenance efficiency.

Residual Feed Intake (RFI)

Residual feed intake (RFI) is the difference between an animal's actual energy intake and its expected energy intake based on the animal's maintenance requirements and levels of production. Thus, efficient animals, which have low RFI values, consume less feed than expected without compromising their production level. RFI cattle, after many years of selection, offer the following advantages:

- 10 to 12 percent reduction in DMI
- An improvement in FCR
- No effects on approximately 34 meat quality traits
- 2 to 3 percent improvement in dry matter and crude protein digestibilities
- About a 25 to 30 percent decrease in methane production per day
- A reduction of nutrient losses in manure of about 15 to 17 percent.

(Basarab et al. 2013).

Low RFI (-RFI) cattle are more productive than high (+RFI) cattle.

Economic Analysis of RFI

An economic analysis of the progeny from -RFI bulls and +RFI bulls which were feedlot fed for 267 days showed a difference in total feed costs of $4,589 to feed 3 pens of 200 cattle that were progeny from the 3 top -RFI bulls compared to 3 pens of 200 cattle that were progeny from the +RFI bulls.
(Basarab et al. 2013).

Top -RFI	Bottom +RFI
3 pens of 200	3 pens of 200
Feed costs: $287,373	Feed costs: $291,962

(161 lb. barley/feeder/year x 6500 market ready feeders means 524 tons of barley saved!)

Making Residual Feed Intake Work for Your Operation

As you determine whether residual feed intake might work for your operation, consider the following points:

- Other measures of feed efficiency have limitations. Consider first what is actually being measured and then how it is measured.
- Group or pen averages of feed efficiency, measured as feed:gain, do not allow you to select for the genetics of the superior animal or select against the genetics of the inferior animal.
- Feed efficiency is a trait of importance to all aspects of the beef cattle industry. Cow-calf producers will see economic benefits from a cow herd with reduced feed costs just as backgrounding and feedlots will benefit from improved feed efficiency.
- RFI does not favor larger animals that gain more. It is independent of body weight and growth, meaning you can find feed efficient animals that also gain well.
- Heavy selection pressure on one trait will have consequences. Feed efficiency should be considered with multi-trait selection so you can include the other traits that are of importance to your herd (growth, fertility, docility, etc.).

Conclusion

This module has introduced you to the idea of residual feed intake as a measure of feed efficiency and how it might work for your operation. The next module builds on this understanding of feed efficiency by examining what the beef industry can learn from other species.

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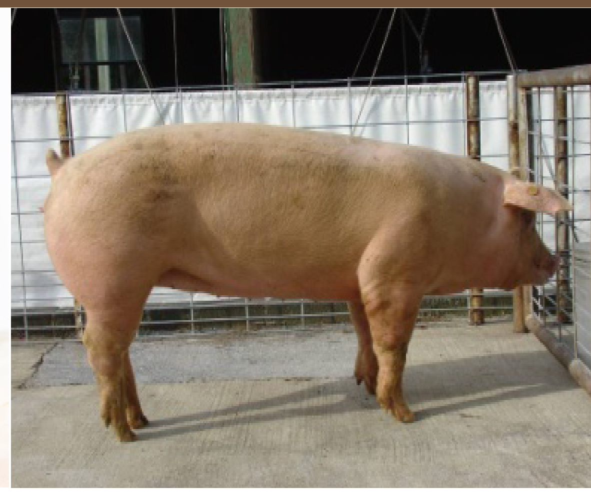


Lessons Learned from Other Species

After completing this module, you will be able to:

- **Explain how genetic selection has improved feed efficiency in other livestock species**
- **Recognize the opportunity for beef producers to increase feed efficiency through genetic selection**
- **Make a case against single trait selection.**


Module 2 - 2

Introduction

In this module, you examine further the justification for feed efficiency by examining the lessons learned from other species of livestock. Although beef producers cannot expect to achieve the feed efficiency levels of other species, there are significant gains to be made. Beef cattle lag well behind other species in improving feed efficiency.

Increased Production Levels Through Genetic Selection

Genetic selection has increased production levels of livestock species considerably (see **Table 2.1 Improvement of Performance in Livestock Species**). Since feed costs are economically the most important costs, the breeding goal in most livestock species is high economic production efficiency combined with relatively low feed intake (Luiting 1990).

Table 2.1 Improvement of Performance in Livestock Species (1960s to 2005)

		Performance[a]		
Species	Trait	1960s	Present	% change
Pigs	Pigs weaned/sow.yr	14	21	50
	Lean meat %	40	55	37
	Feed conversion ration (FCR)	3.0	2.2	27
	Lean meat, kg/tonne of feed	85	170	100
Broilers	Days to 2 kg	100	40	60
	Breast meat %	12	20	67
	FCR	3.0	1.7	43
Layers	Eggs/yr	230	300	30
	Eggs/tonne of feed	5,000	9,000	80
Dairy	Milk production/(cows-lactation).kg	6,000	10,000	67
Average		-	-	>50

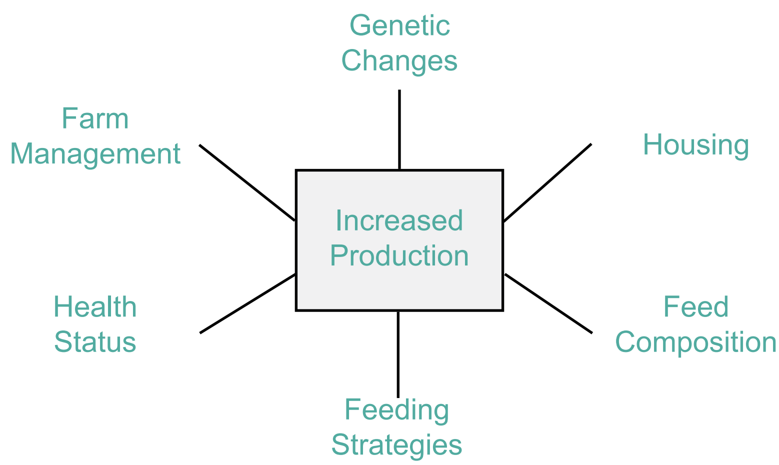
[a]The figures vary greatly between regions and production systems. The table provides an indication of the change, rather than accurate estimates.

(Van der Steen et al. 2005)

The focus of this course is increasing production through genetic selection

Apart from genetic changes, production is also increased by improvement of a number of factors (see **Figure 2.1 Factors That Lead to Increased Production**). (Rauw et al. 1998).

Figure 2.1 Factors That Lead to Increased Production



The integration of science and technology into nearly every facet of farming has resulted in incredible gains over the last 75 years. The average farmer produces 300 percent more food today than in 1950 (Lane and Schaer 2010).Genetics have made a major contribution to this increase.

Genetic Selection of Pigs

Genetic selection has greatly increased production levels in pigs.

Example **Improved Production Levels in Pigs**

See **Figure 2.2 Improvements in Pork Yields from 1980 to 2005** for an illustration of the progress achieved in pigs (Fix et al. 2010).

Pork is now much leaner than in 1980 and, as the production of protein is more efficient than fat, there is an increase in the efficiency of production. The pig has improved its feed conversion ratio from 3.8 lb. to 2.6 lb. of feed per pound of gain from 1972 to 2007. During these 35 years, the pig's final market weight also rose from 220 lb. to 275 lb.

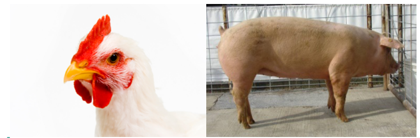
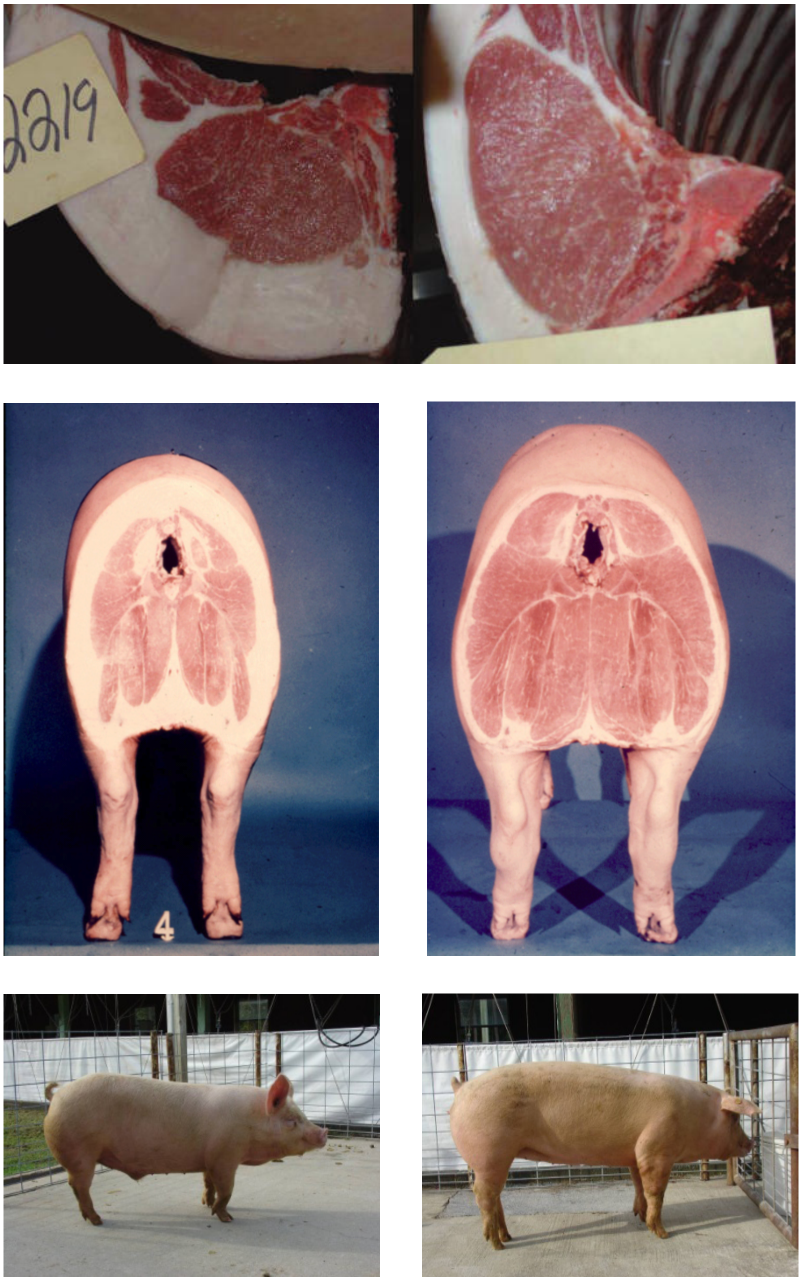


Figure 2.2 Improvements in Pork Yields from 1980 (left) to 2005 (right)



1980 2005

Photos courtesy of Todd See, North Carolina State University.

In pig production, selection is mainly for high growth rate and/or minimum backfat thickness (i.e., high lean tissue growth rate, on low feed conversion, soundness and, recently, litter size). Selection for increased growth rate, efficiency and leanness appears to have resulted in an increase of 30 percent in mature size over 20 years (Whittemore 1994). Within each phase, sow weight gain (> 6:1 FCR), gilt developing gain (<4:1 FCR) and nursing pig gain (<3.5:1FCR) have very different feed efficiency conversion ratios and value of gain, so be clear on which animal type is being discussed when FCR is stated.

Improvements in genetics and feed quality have resulted in substantial increases in yield and improvement of pork quality.

Pigs were produced from a randomly bred control line with frozen semen (1980) and from contemporary sows and boars representing the same breed types (2005) reared under the same conditions. A 15 percent reduction in days to market and 45 percent increase in lean efficiency were almost equally attributable to improvements in genetics and feeding programs (Fix et al. 2010).

Opportunity for Beef Producers

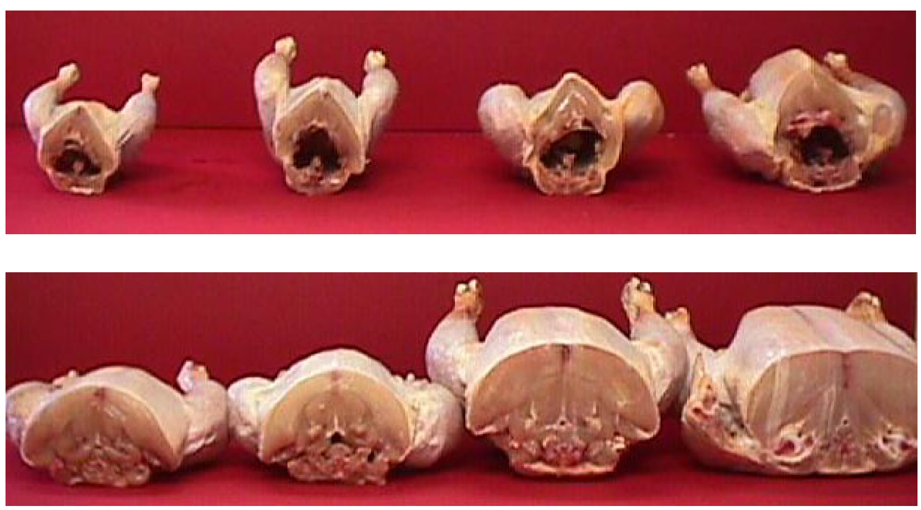
As indicated in the introduction, while it is unreasonable for beef producers to expect to achieve the feed efficiency levels of pigs and chickens, due to the physiological differences of beef cattle (long generation interval and high energy costs for maintenance), it is important to identify cattle that are genetically superior at converting feedstuffs to pounds of meat. Progress on improving the efficiency of beef cattle lags well behind species such as pigs and poultry. This represents a significant opportunity for Canadian beef producers, especially as the cow herd and a significant proportion of the cattle production cycle uses forage and areas that are potentially not used for crops.

Genetic Selection in Chickens

It is estimated that at least 85 percent of the improvement in broiler performance is attributable to genetic changes (see **Figure 2.3 Improved Broiler Performance Over the Past 50 Years**). Combined selection for growth, body composition and feed efficiency continues to deliver 2 to 3 percent improvement per year in the efficiency of meat production, while other traits such as robustness, specific and general disease resistance and absence of metabolic defects have also contributed to this progress (McKay 2008).

The broiler industry boasts an impressive record of improved performance over the past 50 years. Although improvements in health, nutrition and environmental management have contributed, the majority of the change can be attributed to genetic improvement. (Havenstein et al. 2003).

Figure 2.3 Improved Broiler Performance Over the Past 50 Years



Day 43 Day 57 Day 71 Day 85

In North America, the value of FCR is calculated by dividing feed intake by weight gain, and so values of around 1.9 are common for 42-day old birds.

Feed efficiency, together with growth rate, days to market and mortality, are some of the important parameters in assessing the potential of bird strain or feeding program.


The single largest factor affecting feed efficiency, as defined by feed conversion ratio, is energy level of the feed. Five to ten years ago, this was not a major concern because most broilers were fed on diets containing around 3000 kcal/kg in the starter, and up to 3200-3300 kcal/kg in the finisher. Now because of high energy prices, and other management problems, you often see much lower energy values used in one or all diets of a feeding program, and so it is now more difficult to pinpoint a standard energy level in the feed (see **Table 2.2 Effect of Diet Dilution from 35-49 Days of Age on Broiler Performance**). We are also growing broiler chickens over a much more variable time frame, and this also affects feed efficiency.

Example: Feed Efficiency in Broilers

Feed efficiency in a 60 day roaster male, selected specifically for growth rate, is expected to be higher than for a 35 day female destined for the low end cut-up trade. Similarly, there are now broilers grown in most countries of the world, and so environmental temperature will affect maintenance energy need and, hence, classic feed efficiency. These factors now mean that feed efficiency defined by feed conversion ratio can be quite a variable number and, as such, is perhaps losing its significance in terms of comparing broiler performance under a range of field conditions (Leeson 1996).

Table 2.2 Effect of Diet Dilution from 35-49 Days of Age on Broiler Performance

Diet ME (kcal/kg)	Diet CP (%)	49d body wt (g)	Feed intake 35-49d (g)	Feed:gain 35-49d	Energy efficiency (Mcal/kg gain)
3200	18	2950	2580	2.34	7.43
2900	16	2920	2760	2.49	7.19
2600	14	2880	2900	2.72	6.97
2300	13	2910	3270	2.99	6.70
1900	11	2910	3670	3.31	6.37
1600	9	2890	4300	4.01	6.41

Source: Leeson 1996


Lessons from the Pork and Poultry Industries

Think about what you, as a cattle producer, can learn from other livestock industries.

Genetic selection for growth traits has allowed pigs and chickens to become very feed efficient, in addition to increasing lean meat yields and overall body weight.

Genetic selection for growth traits has allowed pigs and chickens to become very feed efficient.

- Pork and poultry, on average, use an estimated 15 percent of their dietary energy consumption to deposit protein and grow lean tissue compared to cattle which only use 5 percent. Add to that the low and slow reproductive rates of cattle (one offspring every 12 months) and the cattle industry cannot expect to make as significant changes to feed efficiency as pork and poultry have.
- Feed conversion ratio is affected by the energy concentration of the diet. As lower energy rations are fed, feed:gain ratios will be poorer.
- The heavier body weights of chickens may be partially to blame for increases in poor health and performance (heart and leg issues).
- The beef industry is in a position to make tremendous gains in feed efficiency through genetic selection because there has not been heavy selection for this trait in the past.

The Case Against Single Trait Selection

Broiler chickens provide the most striking examples of the problems with single trait selection.

Example **Single Trait Selection in Broiler Chickens**

Single trait selection for body weight in broiler chickens resulted in an increasing incidence of heart failure syndrome and leg problems. In poultry breeding programs, selection had been almost for one trait only (i.e., body weight at a certain age, with a high selection intensity and a short generation interval).

In species like cattle and pigs, selection has been less intensive, for more traits and during fewer generations; however, single trait selection has resulted in some problems.

Example: Single Trait Selection in Dairy Cattle

In most dairy cattle breeding programs, selection is mainly for high milk yield. Research shows the presence of undesirable side effects of selection in dairy cattle; selection has made animals more sensitive to metabolic, reproduction and health problems (Rauw et al. 1998).

Like any other trait, selecting for negative residual feed intake (RFI) as a measure of feed efficiency should not be made with single trait selection. Cattle that are desirable for their feed efficiency also need to have desirable performance and desirable average daily gain (ADG). They also need to be structurally correct and obviously fertile if they are to be selected for breeding purposes.

Conclusion

You should now recognize the opportunities for you, as a beef producer, to increase feed efficiency in a manner similar to what has happened in the pork and poultry industries.

The next module on understanding genetic improvement provides more detail on how you might determine your breeding goals and prioritize traits for your marketing situation. It will help you understand the principles behind genetic improvement.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3

Genetic Improvement

After completing this module, you will be able to:

- **Explain the importance of genetics to improved feed efficiency**
- **Use your understanding of breeding values to improve the genetics of your herd**
- **Outline the challenges of selecting for improved feed efficiency**
- **Describe how genomics now has practical use as a breeding tool**
- **Calculate simplified ranges in expected progeny differences (EPDs) once you are better able to understand genetics and heredity and how accuracy affects the values.**

Introduction

The first two modules provided you with the justification for improving feed efficiency; one of these justifications included economic benefit. In this module, you examine genetics which is the study of inheritance. As a producer, you can use this knowledge of genetics for animal breeding and improving the merit of your animals. This course focuses on using genetic improvement principles to select for improved feed efficiency.

Genetics and Animal Breeding

The observed performance, or phenotype, of an individual is the outcome of the interaction between genetics and environment.

P (phenotype) = G (genotype) + E (environment)

Example **Genetics and Environment**

Genetics and environment interact to give us what we observe in an animal.

The bull below (Simmental cross) mated to the group of cows (Angus cross) on the right produced calves destined for feedlot finishing on a high grain ration.

In this course, your focus is on an animal's genetic merit because its genes will be passed on to its offspring.

The calves from the matings on the previous page produced these feedlot steers. On the left, the red steer gained 3.24 lb./day and on the right, the black steer gained 4.18 lb./day on the same barley based ration in the same feedlot. Their phenotype for ADG is the result of the environment in combination with their genetic ability.

ADG 3.24 lb./day

ADG 4.18 lb./day

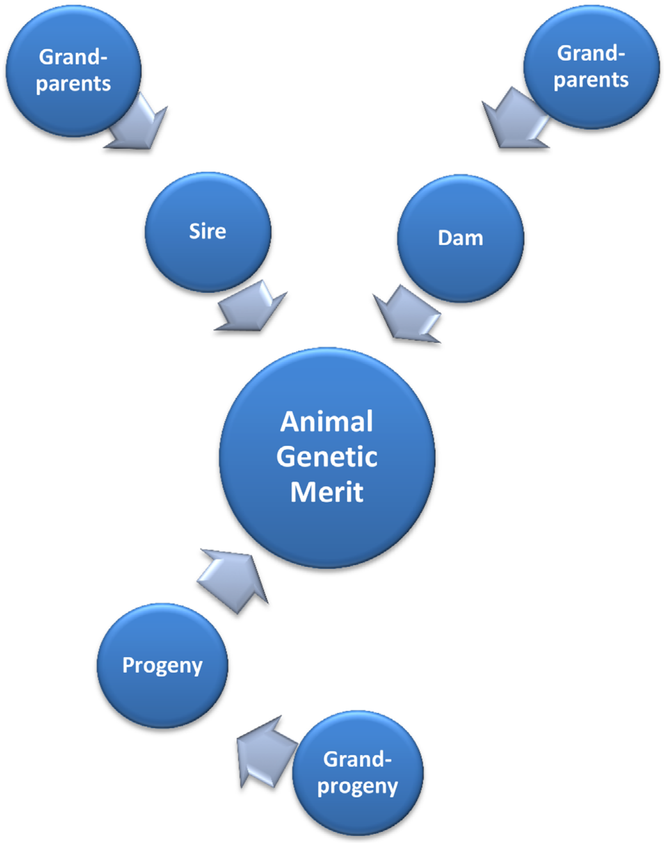
The trait, average daily gain (ADG), for example, shows two animals of similar genetic makeup growing differently because of environmental differences such as age of the dam, management, etc. When you observe an animal, there is a genetic component and an environmental component influencing what you see.

If you just look at an animal, you cannot evaluate its full potential. An animal's true potential for production lies in its genes.

BLUP (Best Linear Unbiased Prediction)

Animal breeders and geneticists are able to determine an animal's genetic merit by analyzing information collected on an animal, its progeny and its relatives (see **Figure 3.1 Sources of Genetic Merit**). This is achieved using a type of mathematical model called Best Linear Unbiased Prediction (BLUP; Henderson 1975). BLUP estimates the genetic merit of an animal, while simultaneously accounting for environmental effects and other possible genetic (e.g., maternal) or non-genetic (e.g., permanent environmental) effects.

Figure 3.1 Sources of Genetic Merit



If you can measure economically relevant traits on animals such as growth rates, fertility, milk production, etc., and record pedigree information (similar to a family tree), you can separate the genetic component of a trait from the environmental component. This allows you to estimate the genetic merit of an animal.

Breeding Values

In order to understand genetic improvement, you need to understand the accuracy and reliability of breeding values. There are usually three main terms used to refer to an animal's genetic merit for a particular trait:

- Estimated breeding value (EBV)
- Expected progeny difference (EPD)
- Predicted transmitting ability (PTA).

When you put the above into a formula, you get:

EPD = ½ EBV and PTA = ½ EBV.

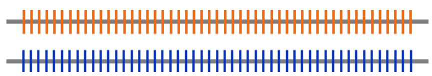
This concept is illustrated below.

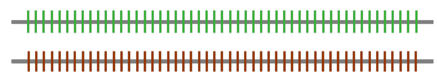
Sire

Dam

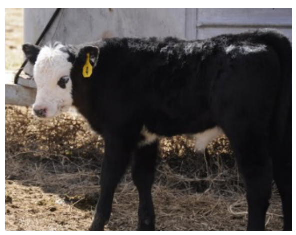
Photo courtesy of J. Cross. Bar Pipe Hereford Ranch, Okotoks, AB.

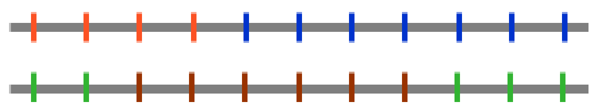
Photo courtesy of D. Goodrich Pure Country Stock Farm, Hardisty, AB.





Calf receives genes from each parent





A calf's genes are comprised of portions from each of the parents.

Both PTA and EPD are used because an animal will pass on half of its genes to its progeny (the other half comes from the other parent) and so is the average genetic merit for a given trait that an animal transmits to its offspring. All breeding values are expressed relative to a "base" animal (those from a particular year from which to make reference for comparison purposes).

Example **Average Breeding Value**

The average breeding value of animals born in the year 2000 is set to zero. Different organizations/breed associations have different bases.

It is important to understand that the average EPD for any trait within a breed is not 0. One reason for this is genetic trend. Genetic trend refers to the improvement in genetics that has taken place over time within a breed due to selection. Over the years, breeders have selected for increased growth, milk production, etc. As this selection has occurred, the average EPDs for bulls within a breed for these traits has also increased and the average EPD for bulls of the most recent calf crop may be considerably larger than 0.

Accuracy and Reliability

Along with each estimate of genetic merit comes a measure of how much confidence you can put in these values. These two measures are:

- Accuracy (r)
- Reliability (r^2).

These are a measure of how closely the estimated genetic merit of an animal reflects its true genetic merit.

Parameters That Influence the Confidence Measure

- Quality and depth of pedigree recording
- Number of progeny and relatives having the phenotype of interest recorded
- Quality of phenotype recording
- Heritability of the trait.

An r or r^2 shows how much an EPD can vary. It depends on the genetic variance of the trait being evaluated. For an example, look at weaning weight (WWT) in **Table 3.1 Weaning Weight and Genetic Variance**.

Table 3.1 Weaning Weight and Genetic Variance

Accuracy (ACC) (%)	± lb.
20	9.0
30	8.7
40	8.4
50	7.9
60	7.3
70	6.5
80	5.5
90	4.0

When you select an animal based on genetic merit, consider accuracy. An increasing accuracy means our confidence in the values also increases.

In **Table 3.1 Weaning Weight and Genetic Variance**, accuracies and the associated 95 percent confidence intervals are shown. If an animal has an EPD of 45 lb. and an accuracy of 20 percent, that animal's true progeny difference will be between 36 lb. and 54 lb. (45 ± 9) 95 percent of the time. The lower the accuracy, the less reliable an EPD will be at predicting the true progeny difference. Therefore, when you are selecting animals based on genetic merit, you need to consider the accuracy.

R&R BeefMaker 66S (photo courtesy of R&R Acres, Airdrie, Alberta)

This bull born in 2006 would have had a low accuracy on all his traits as an unproven (no progeny) yearling bull. However, today as a mature bull with many progeny, his accuracy is quite high.

Determine Range of Weight for Progeny

Using Table 3 and the trait of weaning weight, determine the range expected for his progeny. EPD for WW = 31.1 lb.

1. If the accuracy is 20% ____________________
2. If the accuracy is 70% ____________________

Answer:

31.1 + or – 9 = weaning weights of his progeny being between 22.1 and 40.1 lb. over the breed average 95 percent of the time.

31.1 + or – 6.5 = weaning weights of his progeny being between 24.6 and 37.6 lb. over the breed average 95 percent of the time.

As accuracy increases, it indicates how much we know about an animal's true genetic worth.

Therefore, if the average weaning weight for his breed is set at 575 lb., then his offspring will have expected weaning weights between 597 and 615 lb. when he is an unproven bull. Once he is a proven bull, the expected weaning weights are between 600 and 613 lb. See the table below.

Table 3.2 Weight Range of Progeny

Breed Value (lb.)	EPD	Range of EPD (lb.)	Weight Range of Progeny (lb.)
WW 575	31.1	-9 =22.1	575 + 22.1=597
WW 575	31.1	+9 =40.1	575 + 40.1=615
WW 575	31.1	-6.5 =24.6	575 + 24.6=600
WW 575	31.1	+6.5 =37.6	575 + 37.6=613

Note that the breed average may also change each year, so you must check on the average in each year before you do calculations.

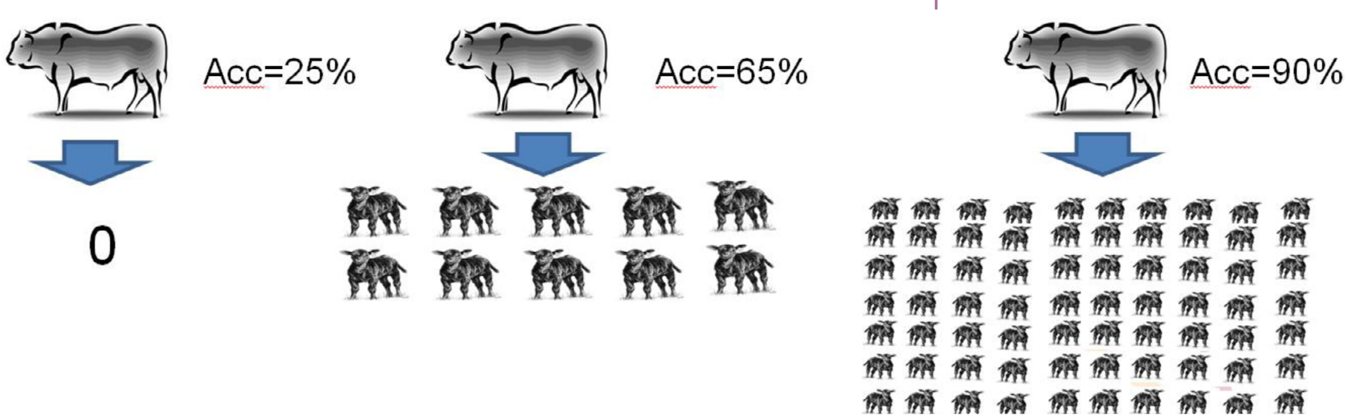
Genetic Change

The parameters already mentioned all come into play when improving the genetics in your herd. Genetic change (ΔG) is primarily a function of four different variables: selection intensity (i), accuracy of the breeding value (r), genetic standard deviation (measure of variation; σ) and generation interval (L). It can be written as:

$$\Delta G = \frac{i \cdot r \cdot \sigma}{L}$$

Why is accuracy important when looking at an expected progeny difference (EPD)? Simply, the lower the accuracy, the more chance there is that the estimated EPD can change. The lower the accuracy, the higher the magnitude of that possible change – there is more risk. See the figure below.

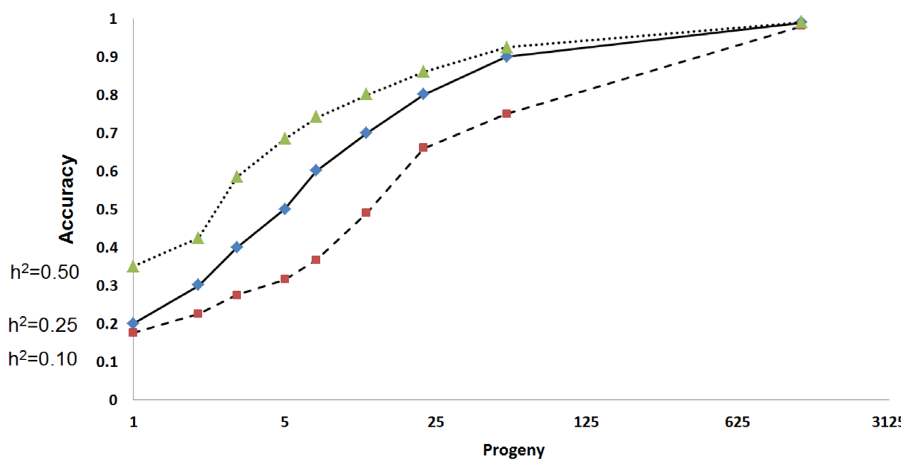
Figure 3.2 Impact of Accuracy on EPD



When an animal is first born, its EPD will simply be a parental average. Depending on the accuracy of the parent's EPD, the newborn's accuracy will be pretty low (around 25%). Once it starts to get progeny on the ground and the progeny's phenotypes are recorded, accuracy will increase. Ten progeny on the ground can give a bump up in accuracy to around 65 percent and up to 90 percent accuracy with 70+ progeny. These increases are different per trait as each trait has a different heritability (the proportion of the total variance in the trait explained by genetics). The more phenotypes recorded on all these animals, the more accurate a producer's selection decisions and the greater increase in the rate of genetic gain. These increases in accuracy are illustrated below.

Highly heritable traits initially have higher accuracies than traits with low heritabilities. However, as progeny from an animal increases, so does the accuracy of predicting that trait.

Figure 3.3 Increases in Accuracy Attributable to Increase in Progeny (observed on an individual for 3 differing heritabilities)



This increase in accuracy at a young age is indirectly reducing the generation interval of breeding. A producer doesn't necessarily have to wait for a bull to be 4 years old (and gone through 2 breeding seasons) to establish a decent EPD accuracy. This contributes further to a quicker turnover of genetics.

Interpreting and Using EPDs

Expected progeny differences (EPDs) provide estimates of the genetic value of an animal as a parent. Specifically, differences in EPDs between two individuals of the same breed predict differences in performance between their future offspring when each is mated to animals of the same average genetic merit. EPDs are calculated for birth, growth, maternal and carcass traits and are reported in the same units of measurement as the trait (normally pounds). EPD values may be directly compared only between animals of the same breed. In other words, a birth weight EPD for a Charolais bull may not be directly compared to a birth weight EPD of a Hereford bull (unless an adjustment is made to account for breed differences).

It is useful to understand where a particular bull ranks within a breed for traits of interest. This ranking will give a general idea as to the genetic merit of the bull compared to others within the breed. It is important to understand that the average EPD for any trait within a breed is not 0. One reason for this is genetic trend. Genetic trend refers to the improvement in genetics that has taken place over time within a breed due to selection. Over the years, breeders have selected for increased growth, milk production, etc. As this selection has occurred, the average EPDs for bulls within a breed for these traits has also increased and the average EPD for bulls of the most recent calf crop may be considerably larger than 0. The following table depicts average EPD values for bulls from the 2002 calf crop for several breeds. The table below provides EPD averages for non-proven bulls.

Table 3.3 EPD Averages for Non-proven Bulls (Spring 2002)

	CE	BW	WW	Milk	YW
Angus		+2.6	+33	+17	+62
Charolais		+1.7	+14.2	+8.8	+24.3
Gelbvieh	104	+1.3	+34	+17	+61
Hereford		+3.9	+34	+12	+57
Limousin		+1.4	+12.3	+4.5	+23.1
Red Angus		+0.4	+28	+14	+49
Simmental	+2.3	+3.3	+36.0	+8.1	+59.1

Due to genetic trend, the average EPD in each breed changes on a frequent basis. Therefore, it is important to utilize the most current breed averages as a basis of comparison. Current breed averages may be found in the sire summaries available from breed associations (adapted from Scott Greiner, Virginia Cooperative Extension, Virginia Tech and Virginia State University factsheet 400-804. 2009).

For more information on understanding EDPs , refer to http://www.pubs.ext.vt.edu/400/400-804/400-804.html

Single Trait Selection Indexes

There are many economically desirable traits. The question, then, is which ones do you aim to improve? If you select for a single trait, you could inadvertently be negatively influencing another trait because of an unfavorable genetic correlation.

Example **Selection for a Single Trait**

If you select for increased milk production in dairy cattle, you may increase fertility problems. If you select for increased weaning weight, you may increase calving difficulty.

Pleiotropy and Linkage

Mechanisms behind a genetic correlation of traits include pleiotropy and linkage. Pleiotropy is when the same part of the genome (or genetic code) affects different traits. Linkage is where parts of the genome that affect different traits are inherited together. Because genetic correlation exists between traits, selection indexes become useful.

Multi-Trait Selection Indexes

After breeding values are derived for traits that have been identified as important, different pressures or weightings can be applied to each trait and summed to form an index. These are referred to as multi-trait selection indexes.

Example **Selection of Two Traits**

Imagine just 2 traits–weaning weight (WWT) and birth weight (BWT). There is a positive genetic correlation between WWT and BWT. This means if you select for increased WWT, BWT is also going to increase. Increased BWT may not be desirable as it leads to calving difficulty (you may get away with it one year but do it year after year and you will have problems). To offset this, a positive weighting is placed on WWT and a negative weighting is placed on BWT. Depending on the magnitude of the weighting, BWT will remain constant or increase marginally. If you want BWT reduced, you use a stronger negative weighting. If you were to then rank animals based on the sum of these two parameters, the animals at the top would be those that have good WWT genetic merit while simultaneously having genetic merit for an equal or lower BWT. Animal #1 in **Table 3.4 Index of Eight Traits** illustrates this combination of desirable traits, BWT and WWT.

The weightings that are placed on the individual traits are estimated using selection index methodology. This methodology takes into account a lot of variables such as genetic parameters of the traits, population structure and an economic value for each trait. Generally, most traits with a higher positive value are preferred over those with negative values except in the cases of birth weight (BW), RFI and cow weight where a negative value is more desirable.

The previous example is for just two traits. You could likely come up with 15 or so traits that are important to efficient production. **Table 3.4 Index of Eight Traits** is an index which takes into account eight traits. It shows animals ranked 1 to 5 and those ranked 101 to 105. Look at the differences in the component traits.

Table 3.4 Index of Eight Traits (showing top 5 and bottom 5 animals from a group)

Animal #	Rank	Index	BWT	WWT	Yearling_WT	Heifer_WT	Backfat	Scrot	Milk	Cow_WT
1	1	162.58	-3.93	28.58	126.73	35.24	-0.40	1.58	40.34	-90.07
2	2	156.11	2.76	46.97	124.33	41.68	0.20	3.22	31.44	-58.88
3	3	155.54	4.87	49.71	95.09	12.94	-0.22	4.65	23.18	-67.29
4	4	154.12	5.59	60.56	181.93	95.94	-0.26	2.15	48.87	54.83
5	5	153.98	2.57	35.41	137.73	39.49	0.35	2.94	43.20	-59.30
6	101	138.07	2.86	25.04	86.22	47.28	0.16	2.77	18.34	-19.28
7	102	138.03	7.00	43.00	134.23	76.74	0.25	1.24	37.59	8.43
8	103	137.98	2.32	41.98	135.03	14.95	0.38	1.10	37.18	3.61
9	104	137.93	6.02	47.07	124.73	76.68	-0.14	1.18	30.75	11.70
10	105	137.80	-4.48	-6.05	13.16	-106.89	0.01	0.01	17.20	-123.87

Example — Selection Using Eight Traits

Look at animal #4 in Table 3.3. It looks pretty good for all traits; however, what is preventing this animal from ranking higher than 4th place is its mature cow weight (a positive breeding value is usually undesirable). There is a high negative weight associated with mature weight as there is a significant dollar cost associated with maintaining a larger cow throughout its lifetime.

You can look at other animals in the table to see that an animal who may look good for a lot of traits may have less desirable values for other traits or vice versa.

Explain Ranking

Look at animal #1. Explain why it is ranked first.

Look at animal #6. Explain why it is ranked 101.

Answer:

Animal #1.
A low Cow WT in combination with superior milk, plus a low BWT with high WWT and Year WT.

Animal #6.
Weaning Wt and Yearling WT in addition to milk are the poorest of the example animals with only #10 showing poorer results in these categories.

Selecting for Improved Feed Efficiency

Some traits are difficult to select for. There is debate in the scientific literature whether feed efficiency (usually RFI) should be explicitly included in the breeding goal. The question is whether improved RFI should be the goal or whether the components of RFI (feed intake, liveweight and ADG) should be included separately with relevant weightings placed on each trait.

Lower feed intakes with acceptable gain and performance should be a breeding goal.

There is no doubt that RFI has an economic weight – this is the value of improving feed intake.

Example — Feed Intake as a Goal Trait

In Ireland their beef selection index includes feed intake as a goal trait rather than RFI but, in an industry/country where only breeding values are published and not combined into an index, breeding values for RFI (or RIG, Residual Intake and Gain) are seen to be available.

In growing animals, including the component traits of RFI in an index is mathematically equivalent to including RFI. In addition to selecting for feed efficiency, using RFI, RG or RIG is useful for the following:

- Rank a group of animals for feed efficiency
- Model biological feed efficiency
- Evaluate different diets for predicting animal performance
- Investigate trends for feed efficiency genetic merit over time.

For an in depth discussion on this topic, view Berry and Crowley (2013).

Selecting for reduced feed intake may also be an easier concept to understand than selecting for RFI. However, if selecting for RFI is thought of merely as selecting for feed intake corrected for liveweight and gain, it may be better understood and adopted.

To date, the concept of RFI has been difficult to understand and therefore has not been readily adopted by the beef industry. Because you do not want to select cattle only for reduced feed intakes, since that could lead to smaller animals that do not gain well, you have to be careful to make sure you understand that lower intakes with acceptable gains and performance are the goals of your breeding program.

Heritability of Traits

Heritability is the proportion of variation in a trait that can be explained by (additive) genetic differences and so can be written as:

$$\frac{\sigma_a^2 \quad \text{(genetic variance)}}{\sigma_p^2 \quad \text{(phenotypic variance)}}$$

Depending on the trait, heritabilities differ. **Table 3.5 Heritability of Different Traits** gives approximate heritabilities of different traits.

Although traits with low heritabilities require more effort to get observable genetic gain, it is still possible to make gains.

Table 3.5 Heritability (h^2) of Different Traits

Trait	h^2
Milk Fat and Protein	0.50
Feed Intake	0.40
Liveweight	0.40
Feed Efficiency	0.35
Milk Yield	0.35
Average Daily Gain	0.30
Health	<0.10
Fertility	<0.05

Low heritability = <0.20

Moderate heritability = >0.25-0.45

High heritability = >0.45

Example Traits with Low Heritability

Traits with low heritabilities (fertility and health related traits) require a lot more effort to get higher breeding value accuracies and make observable genetic gain through measures such as accurately recording phenotypes, proper trait definition and higher selection pressure; however, it does not mean that genetic change is not possible.

Genomics

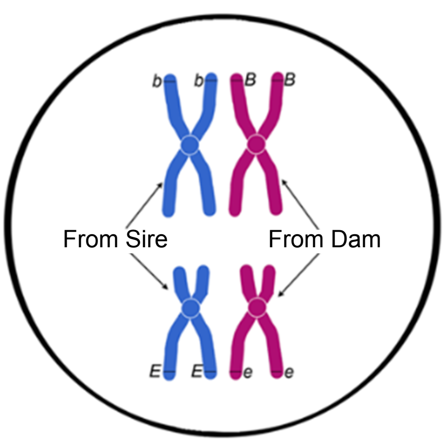
Genomics is the branch of molecular biology concerned with the structure, function, evolution and mapping of genomes. In the last decade, genomics has been developed as a useful and affordable breeding tool.

The genome is the complete set of genes present that make up an organism.

Example **Cattle Genome**

For cattle, the genome is 6 billion base pairs long or, simply, their genetic code is made up of 3 billion pairs of letters. Specifically, these letters are A, C, G and T: adenine, cytosine, guanine and thymine. Cattle have 30 pairs of chromosomes (see 1 pair illustrated below) that make up their genome (on average, 100 million base pairs/chromosome); one member of the pair is from the sire and one is from the dam.

About 1 percent of a chromosome actually represents genes that are expressed. It is this in which we are interested. Cattle have approximately 25,000 genes. Take the analogy of a newspaper; there is a lot of information in a newspaper but there is only some of it that interests you. You are not going to read every word but, from what you do read, you will “get the picture”.



Website reference: http://cyberbridge.mcb.harvard.edu/mitosis_2.html

Using Genomics as a Breeding Tool

From an animal breeding point of view, you are interested in the difference in genetic code between animals. You would like to be able to predict an animal's future value right at birth.

Example **Difference in Genetic Code**

One animal has high milk production and one has average milk production. What you need to know is the difference in their codes so that you can identify high producing animals in the future.

A SNP is a difference in one of the 6 billion base pairs in each genome.

An animal's genetic code, or genotype, can be read from its DNA through genotyping. This is done by looking at markers on the genome called single nucleotide polymorphisms (SNP). SNP testing is commercially available and is now cost effective enough to be used by producers. Different densities of tests exist (e.g., <2,000 SNP, 6,000 SNP, 50,000 SNP, 800,000 SNP) with higher density tests potentially giving greater insight and predictive ability. Density refers to the number of SNPs or markers a test is able to read.

In order to develop the predictive power of SNPs, researchers first genotype animals on information already known so differences in genotype can be attributed to differences in animal performance. This is called "training".

Example **Prediction Model**

Formula for genetic change:

$$\Delta G = \frac{i \cdot r \cdot \sigma}{L}$$

You have five animals with different weaning weights (WWT): three with low WWT and two with high WWT as shown below. When their genotypes are analyzed, a SNP is identified (highlighted in red) that can be used in the future to act as a predictor because it explains some of the variance in that trait.

Animal 1	…a c t a c g a…	Low WWT
Animal 2	…a c t a c g a…	Low WWT
Animal 3	…a c t a c t a…	High WWT
Animal 4	…a c t a c t a…	High WWT
Animal 5	…a c t a c g a…	Low WWT

The current accuracy for feed efficiency genomic prediction ranges from 0.29-0.56, depending on how closely the candidate is related to the training population.

Since most traits are polygenic (differences in phenotype are attributable to two or more genes), many SNPs are usually incorporated into a prediction model.

From the formula expressing genetic change, genomics has an impact on two components: accuracy (r) and generation interval (L). Using genomic information from an animal will increase the accuracy of a breeding value or facilitate a breeding value to be estimated that was initially not possible because of pedigree data not being available. This, in turn, leads to a reduction in the amount of time required to obtain information from an animal as soon as it is born. DNA can be collected on an animal the second it is born. Because of this, a genomic breeding value (GBV) or a genomic prediction can be generated very early on in life to the same accuracy as a few years later on in life.

DNA testing holds the greatest promise for economically relevant traits, like RFI, which are currently expensive to measure.

Example: Using Genomics to Identify High Milk Production

Assume you have a dairy bull. To start increasing his accuracy for his milk production EBV, it will be nearly 5 years until his first daughters finish their first lactation. With genomics, a very similar accuracy can be achieved in the first year. This allows you to identify the best bulls and use them earlier. In effect, this is reducing the generation interval.

In addition to using genomics for generating breeding values, this DNA technology is also used for the following:

DNA technology has many uses.

- Parentage verification (e.g., in multi-sire pastures)
- Testing for traits such as tenderness (that can only be measured after the animal is slaughtered)
- Screening for health traits
- In the future, potentially identifying the best management and/or breeding group for an animal (e.g., diet).

Example: Using Molecular Breeding Values

A feedlot can use molecular breeding values to sort groups of feeder calves into management groups to take advantage of their strengths and weaknesses (e.g., frame score, weight, feed intake, gain and fat cover). Growth implants would not have to be used in all the cattle, only the ones with the genetic makeup that benefits from them.

Sort Feeder Calves

Group 1	Group 2
←	→
Average cattle, moderate weight and fat	Genetically superior in marbling
Benefit to re-implant	Do not implant (for a branded beef market)

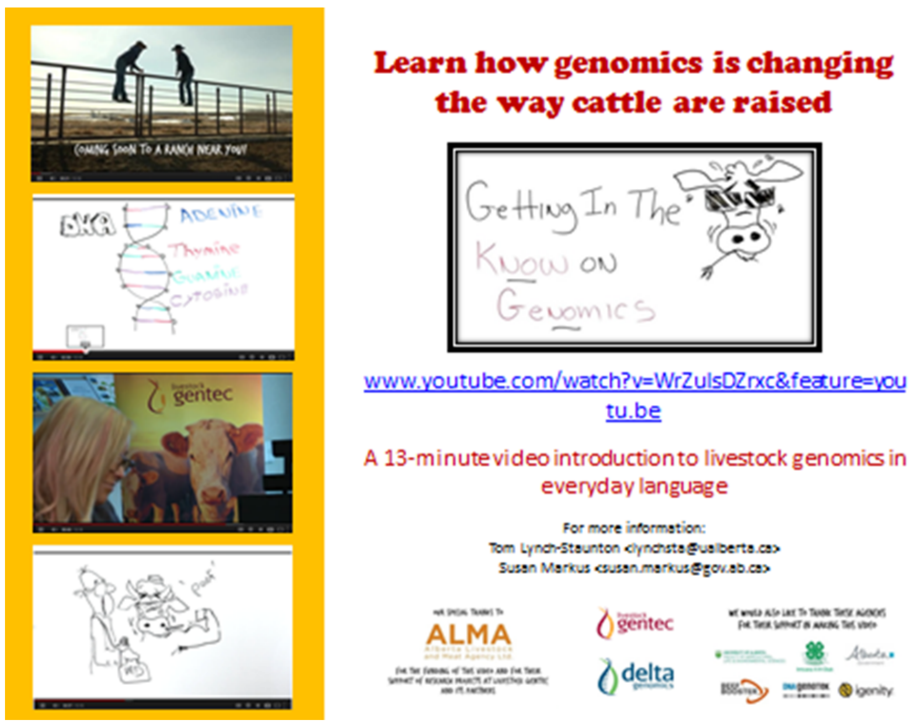
Conclusion

You should now have an understanding of how you can use genetics for animal breeding and improving the merit of your animals. More specifically, you should now understand how you can select for improved feed efficiency using genetic improvement principles.

In the next module, you will focus on breeding plan goals and use the material to help you select your own breeding goals.

Some of the material in Module 3 is quite technical. For a further introduction to livestock genomics, see the video described below.

View this 13 minute video to get a better understanding of how genomics technology can benefit your beef operation.



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4

Evaluate Successful Breeding Plans

After completing this module, you will be able to:

- **Develop some breeding plan goals for your beef herd**
- **Use the practice of minimum culling levels or index rankings to select for several desirable traits**
- **Explain the difference between residual feed intake (RFI) and feed:gain**
- **Outline the effects of selecting for feed efficiency on other traits.**

Introduction

The first three modules looked at the justification for improving feed efficiency and the genetic improvement principles that allow you to select for improved feed efficiency. In this module, you start to determine your breeding goals and learn how to select livestock to meet these goals.

The objective of any breeding program is to ensure that desirable genes are transferred from one generation to the next. Once you have developed a breeding objective that reflects market requirements, you can select livestock that express traits that suit your breeding objectives.

Traits for Selection Goals for Purebred and Commercial Breeders

Some traits that both purebred and commercial breeders consider for selection goals include:

- Low birth weight for ease of calving
- Weaning weight or pre-weaning rate of gain
- Yearling weight
- Post-weaning rate of gain
- Efficiency of feed conversion
- Mature size
- Conformation and structural soundness: breed standards
- Docility and ease of handling: temperament
- Mothering ability
- Fertility
- Carcass traits
- Characteristics of fat deposition
- Health status and resistance to diseases
- Cow reproduction efficiency measures (e.g., calf weaning weight:cow weight at weaning and ratio of calf birth weight to cow weight).

Cow Reproduction Efficiency Targets:

A beef cow should wean a calf at or before 9 months of age weighing at least 45 percent of her weight. (e.g., 1350 lb. cow is expected to wean a calf at least weighing 608 lb.).

That same cow is expected to be able to give birth to a calf with a birth weight 7 percent of her weight (e.g., 95 lb.).

Selection for Several Traits

Do not select for an inordinately large number of traits at one time. Not only does it impair genetic change, but implementation is difficult. Ideally you should select six or fewer traits at a time.

Select Traits

Look at the list of traits on the previous page. Identify up to six that you might choose. Consider other traits not on the list and list one more. Rank your list of seven traits from most important (1) to least important (7).

List of Traits	Rank from 1 to 7

Once you have defined a breeding goal, keep in mind that there is an optimum to what you can accomplish with limited resources.

Breeding goals can be influenced by your location, resources and marketing plans.

Example — Environmental Limitations

Milk production may be limited if the cattle are fed low quality forages and are not given the opportunity to receive grain or concentrate supplements that would have increased their milk production due to their genetic potential.

Practices for Selecting More Than One Trait

There are three common practices for selecting for more than one trait at a time:

- Minimum culling levels
- Tandem selection
- Index selection.

Should a breeder select for a certain trait or cull against another trait?

Minimum Culling Levels

With minimum culling levels, you attach a value to all the selected traits and set a minimum index level. You then cull any individual that does not achieve the desired value for one or more traits. See **Table 4.1 Desirable Heifer Production Traits**.

Example **Minimum Culling Levels**

Culling levels for replacement heifers could be based on:

- Docility–classify temperament as calm, average or wild; cull if wild
- Weaning weight >600 lb.
- Fertility–must be bred and confirmed in calf by 18 months of age
- Mothering ability–based on the dam's milking ability, classify as good or poor milker and cull poor milkers' progeny.

Table 4.1 Desirable Heifer Production Traits

Animal ID	Docility	Weaning Weight	Pregnant	Milk	Index
12Z	Calm	558	Yes	Good	95
19Z	Calm	664	Yes	Good	105
23Z	Wild	611	No	Good	65
31Z	Average	695	Yes	Poor	87
42Z	Calm	627	Yes	Good	102

Based on our minimum culling system, heifers 12, 23 and 31 will be culled for not meeting minimum production targets.

Tandem Selection

With tandem selection, you select one trait from an array of traits and, once the trait is established within the herd to your satisfaction, the next trait receives attention. The process is maintained until you have accounted for all the traits in the array.

Example Tandem Selection

Using the heifers and their data from **Table 4.1 Desirable Heifer Production Traits**, with tandem selection you could select weaning weight first. After you cull 12Z for low weaning weight, mothering ability through the trait of milk production could become the focus for the next generation.

Index Selection

With index selection, you measure all the chosen traits concurrently and include the relevant measurements in a formula which is used to obtain a selection index (breeding value) for each individual on which you then base your selection.

Example Index Selection

Use the heifer data in **Table 4.1 Desirable Heifer Production Traits**, but now add an index system that ranks weaning weight almost twice as high as the fertility and mothering ability and ranks docility as the least important of the four traits. This means that 23Z and 31Z are culled for sure.

Multi-Trait Indexes

While feed efficiency is a very economically relevant trait, if used in single trait selection, it has its drawbacks. Optimal breeding programs use a multi-trait selection approach where animals are indexed based on their genetic merit for a combination of traits. The selection pressure or "weighting" on each trait is influenced by its economic relevance, its (co)variance components and, in some cases, the desire to change a given trait.

To illustrate, six bulls are ranked, based on a terminal and maternal index. In a terminal index, more weighting will be put on the traits that increase profit in a terminal animal (e.g., slaughter steers) and in a maternal index more weight is placed on those traits that contribute to increased profitability in the maternal herd (e.g., replacement heifers).

Table 4.2 EPDs of Six Bulls for Seven Traits shows the EPDs of the six animals for seven traits: calving ease (CE), maternal calving ease (CEM), weaning weight (WWT), yearling weight (YWT), Milk, RFI and mature weight (MWT).

Table 4.2 EPDs of Six Bulls for Seven Traits

	CE	CEM	WWT	YWT	Milk	RFI	MWT
Animal1	0.1	0.05	6	4	3	0.05	10
Animal2	0.05	0.02	4	8	4	-0.075	-15
Animal3	0.12	-0.04	10	8	-0.5	-0.125	-12.5
Animal4	-0.08	0.09	15	20	10	-0.1	15
Animal5	0.4	0.4	2	9	-2	0.1	12
Animal6	-0.15	0.02	2	4	8	0.25	-3

Using an economic model, along with the phenotypic and genetic parameters, geneticists can generate economic weightings for each trait and sum them up to create a multi-trait selection index. Generally, breed associations have agreed on the parameters that define the indexes they use, but you can have indexes created for your specific situation.

See $Profit Index created by BIO in Module 10-3.

Table 4.3 below shows an example of relative weighting percentages for a maternal and terminal index.

Table 4.3 Relative Weighting Percentages for a Maternal and Terminal Index

	CE	CEM	WWT	YWT	Milk	RFI	MWT
Maternal (%)	10	20	10	10	20	(-)15	(-)15
Terminal (%)	15	0	30	30	0	(-)15	(-)10

Note that RFI and mature weight have a negative weighting because a lower value in both EPDs is more desirable. If you multiply and sum up the values, you see that all bulls re-rank based on which index you look at (see Table 4.4). However, Animal3 ranks second in both indexes and so could be considered a good all round bull. Use indexes to compare one animal to another to discover how much extra profit per progeny will result.

Maternal indexes put emphasis on calving ease and milk while terminal indexes emphasize growth (weaning and yearling weights). RFI is equally important in both situations.

Make use of an expert to design selection indexes. Correct design is important to ensure good results. See Module 10 for resources to locate experts in index creation.

Table 4.4 Ranking of Different Bulls continues to show how different bulls are more suitable to different end goals.

Table 4.4 Ranking of Different Bulls

	Maternal Index	Maternal Rank	Terminal Index	Terminal Rank
Animal1	1.13	5	20.08	6
Animal2	42.70	1	51.19	3
Animal3	35.98	2	66.87	2
Animal4	32.75	3	90.03	1
Animal5	-9.95	6	21.45	4
Animal6	26.02	4	20.40	5

In most beef herds, minimum culling levels are used. To overcome the difficulties identified in **Table 4.5 Disadvantages of the Various Selection Practices** with minimum culling levels and tandem selection, index selection was developed. Although genetic gain for any one trait is slow, overall gain is maximized using index selection.

Table 4.5 Disadvantages of the Various Selection Practices

Minimum Culling Levels	Tandem Selection	Index Selection
Where an individual is weak in one trait but strong in one or more other traits, the relevant individual and its strong points are culled.	When selection for the second or higher level traits in the selection array are being selected, the traits selected for previously tend to sag.	Although genetic gain on any one trait is slow, overall gain is maximized using this selection procedure.

Generation Interval – Manage Expectations

The generation interval is the average age of parents when their offspring are born. Shortening a generation interval allows you to make genetic change faster. In beef production, where seasonal breeding is applied and the bulls are of an average age of 3, the mean age of the cows in a herd, at a set date in the calving season, provides a good estimate of generation interval.

Example Generation Interval Calculation

Bull average age = 3 years

Cow average age = 7 years

3 + 7 = 10

Average age of parents: 10/2 = 5

Generation interval = 5 years

If you allow heifers to calve at two years of age, you can reduce the generation interval by one year compared to calving heifers for the first time at three years of age. However, age at first calving has a smaller effect on generation interval. The major effect on generation interval is replacement rate in the breeding herd as shown in **Table 4.6 Replacement Rate of Heifers**.

Table 4.6 Replacement Rate of Heifers (30% replacement rate compared to 15%)

	Average Cow Age (years)	
	30% Replacement	15% Replacement
Year 1	7	7
Year 2	5.5	6.25
Year 3	4.5	5.6
*Generation Interval in Year 3	(4.5 + 3) / 2 = 3.75	(5.6 + 3) / 2 = 4.3

*Assumes bulls are 3 years of age on average.

Example Reducing Generation Interval

If you replace 20 percent of the cows in a herd annually, cows remain in the herd for 5 years from date of first calving. If you replace 25 percent of cows annually, cows remain in the herd for 4 years from date of first calving, thus reducing generation interval by one year. Where cows remain highly productive to a relatively old age, replacement rate can be reduced to 10 percent. In this case, although generation interval is then low, selection pressure on heifers is high.

This means that because many more cows are being replaced each year, the criteria upon which heifers are selected becomes broader. For example, with high selection pressure, the top 10 percent of heifers are selected, whereas with a lower selection pressure, the top third of heifers are selected, allowing more heifers to make the cut.

The higher your replacement age, the lower the average age of your cow herd, resulting in a shorter generation interval to see genetic change.

Increasing generation interval affects selection differential. As replacement rate increases, selection intensity decreases.

Manage Your Expectations

As a breeder, you are often faced with the fact that if selection for a trait is continued for a long time, that trait reaches a level beyond which further improvement is limited and slow. Geneticists say a selection plateau has been reached. Do not despair; genetic variation continues because of the multitude of cattle breeds to which we have access and, for most traits, a large number of genes and variants contribute to that trait. New mutations also add to the variation existing for a trait. In many cases there is no sign of a trait reaching a plateau (e.g., milk production) although for some traits there will be biological limits (e.g., days to harvest in broilers or backfat thickness in pigs). (Adapted from: South African Agriculture, Environmental Affairs and Rural Development)

Effects of Residual Feed Intake (RFI) on Other Traits

Seedstock producers and breed associations have effectively used expected progeny differences (EPDs) to improve the genetic merit of their cattle. These have been primarily for traits including growth and carcass which have put an emphasis on income and revenue generation. As a result, producers place a high value and level of importance on growth related traits to sustain their operation. What has been forgotten to some extent is the selection for factors, such as feed efficiency, that could lower costs within the production cycle.

In order to continue generating income, enhance sustainability and save costs, as a beef producer you need to measure and select for inputs and not just outputs. Selecting cattle for their feed efficiency using the RFI trait is currently the best measure of metabolic efficiency, or energy conservation, because it is independent of body weight, average daily gain and backfat thickness. In any population, there is variation in feed efficiency; there will be individuals that can achieve high rates of gain with low feed intakes just as there will be individuals achieving low rates of gain with high feed intakes and others in between. The challenge comes in measuring cattle for feed efficiency, interpreting the numbers and using the data for genetic progress.

Refer to **Figure 4.1 Correlation Between Growth and Animal Size** to see the range (-2.4 to +2.0 kg DM/day) in RFI for a group of cattle fed the same under similar conditions.

Relationship Between RFI and Feed Efficiency

Feed efficiency (FE) is traditionally measured as the feed to gain ratio and is positively correlated to residual feed intake (RFI). Genetic improvement in RFI will result in a corresponding change in FE. Unlike FE, however, RFI is not correlated either phenotypically or genetically with average daily gain (ADG). This means that genetic improvement in RFI will not result in a change in ADG.

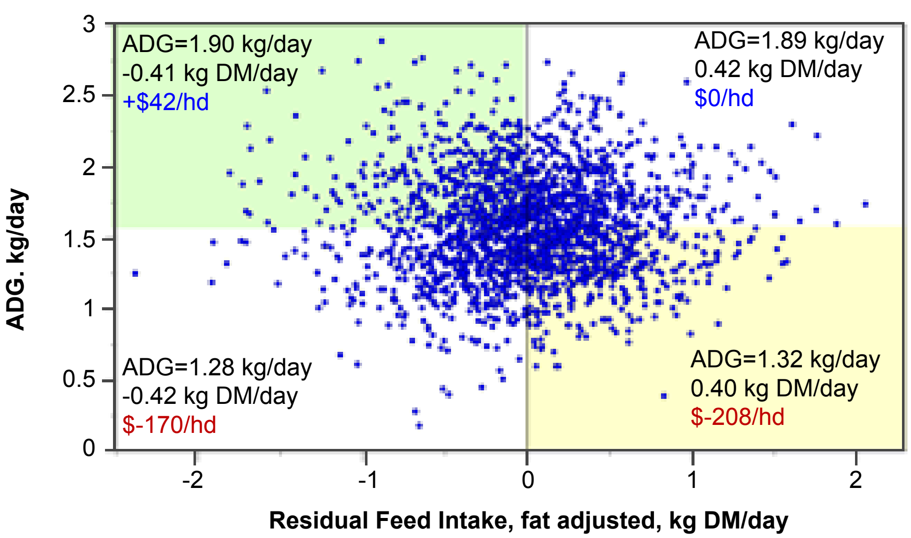
Genetic improvement in RFI results in a corresponding change in FE.

RFI and Feed:Gain

It is critical that you understand that RFI and feed:gain are not the same thing. Selection for animals with higher growth rates (ADG) without consideration of their feed intake inevitably leads to a population of cattle with increased maintenance requirements, higher feed requirements and intake, resulting in animals with higher manure, methane and carbon dioxide production. There has been a trend in both the pig and beef cattle industries over the last 25 years to select for increased growth rate, efficiency through feed:gain and leanness which appears to have resulted in an increase of 30 percent in mature size (Whittemore 1994).

The most profitable cattle fall in the top left quarter. These cattle have high average daily gain and eat the least amount for their superior performance.

Figure 4.1 Correlation Between Growth and Animal Size
(each dot represents an animal)



Correlations (r_p & r_g) are near zero

N = 2029 feeder heifers and steers

Note: Same feeder cost and price, transportation, veterinary and medicine, interest, yardage, death loss and marketing costs

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

Figure 4.1 Correlation Between Growth and Animal Size illustrates how RFI and ADG need to be considered together. Each dot is an animal. Feed values in $/hd represent the extra cost ($-170 or $-208) to feed poor gaining cattle whether feed efficient or not, or feed savings ($+42) compared to high feed intake and high ADG cattle in the upper right quadrant.

- The top left quarter represents those cattle with high ADG and -RFI (feed efficient)
- The bottom left quarter is low ADG and -RFI
- The top right quarter shows cattle that are +RFI (feed inefficient) with high ADG
- The bottom right hand quarter shows those animals with +RFI and low ADG.

Clearly, the most profitable cattle will fall in the top left quarter because they are eating the least amount for their superior performance. Traditionally, we have been selecting cattle from the top half of this graph because we could easily measure ADG and were unaware of the potential of RFI until recently.

As a cattle producer today, you have the advantage of knowing the benefits of ADG with RFI and can focus your genetic selection on the top left quarter. This creates a herd of cattle with reduced feed costs compared to those cattle selected from the top right side.

Effects of Selecting for Feed Efficiency on Other Traits

Research (from J. Basarab, Tiffin Conference 2012) has shown that selection for low RFI (efficient cattle) will have:

- No effect on growth, carcass yield and quality grade
- Reduced feed intake at equal weight and ADG
- Improved feed to gain ratio by 10 to 15 percent
- Reduced net energy of maintenance and reduced methane and manure production by 10 to 15 percent (reducing the carbon footprint of cattle)
- Little if any effect on age at puberty
- No negative effect on pregnancy, calving or weaning rate
- Little effect on bull fertility
- Positive effect on body fatness or weight particularly during stressful periods
- Reduced feed costs by:
  $0.07-0.10/hd/d feeders and $0.11-0.12/hd/d in cows.

Table 4.7 shows phenotypic and genetic correlations between RFI and other traits.

Table 4.7 Correlations Between RFI and Other Traits

Traits	Direction in Low RFI	Phenotypic and Genetic Correlation
DMI	lower intake	0.60 to 0.79
FCR	improved	0.53 to 0.88
Feeding behaviors	lower	0.18 to 0.57
Cow productivity	no effect	0.03
34 meat quality traits	no effect	-0.09 to 0.12
DM & CP digestibility	2-5% improvement	-0.33 to -0.34
CH_4 prod. (g/day)	lower	0.35 TO 0.44
CH_4 yield (g/kg DMI)	slightly higher??	------

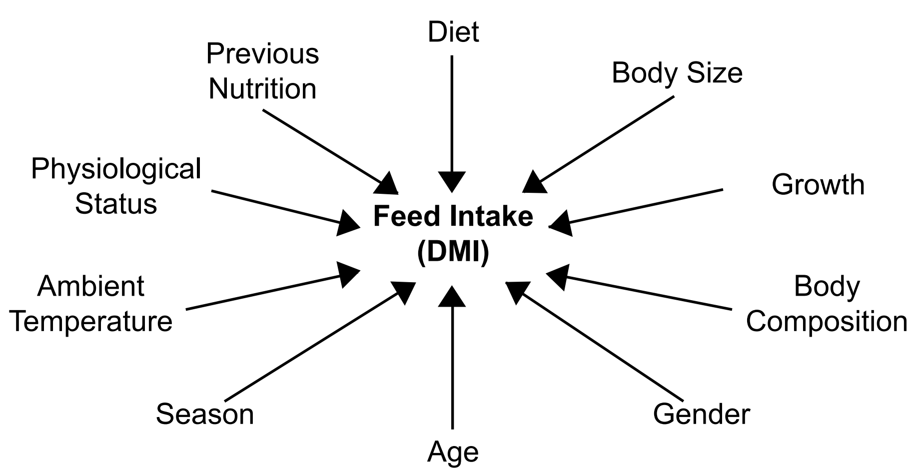
Summary of 20 studies from Australia, Canada, Ireland and USA.

Correlations refer to the relationships between RFI and traits listed with 1 or 100 percent being a perfect relationship. For example, genetic correlation of 0.88 with FCR in the above table means (1-0.88) 0.12 or 12 percent of feed conversion ratio is explained by factors other than RFI when considering genetics, whereas 1-0.53 or 0.47 (47 percent) of FCR is explained by factors other than RFI when considering the animal's phenotype.

Relationships Between Feed Efficiency and Other Important Production Traits

In this section, you examine some of the relationships between RFI and other traits of importance.

Figure 4.2 Factors Affecting Actual Feed Intake (DMI) of Cattle



For an explanation on the difference between phenotypic and genetic correlations, see Module 3 Genetic Improvement.

Most of these factors are either equal between animals during a standardized feed intake test (e.g., gender, season, ambient temperature and physiological status) or are adjusted for, such as body size, body composition and growth, so that we can make direct comparisons between animals. Note, however, that considerable within- and between-animal variation does exist in DMI and measures of feed efficiency.

Diet Type and Breed Type

RFI measured in animals fed a grower diet and then measured again on a finisher diet is positively correlated. This means the animals tend to rank similarly on both diets. The same is also true of RFI measured post-weaning in heifers and RFI measured again later in life as mature cows.

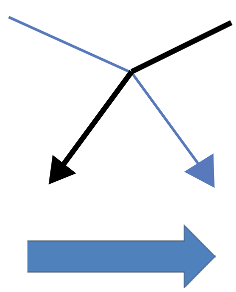
Other Research On RFI

Other research showed that some animals do re-rank, meaning some will have a positive RFI or be inefficient in one test and then when tested again are efficient or have a negative RFI. This level of re-ranking for RFI, DMI and ADG occurred whether the diet changed from a grower to finisher diet or stayed the same from feeding period to feeding period. Such re-ranking was due to:

- Body weight and feed intake measurement error
- Animal variation in response to compensatory gain
- Animal variation in efficiency with animal maturity
- Animal variation in diet digestibility due to differences in feeding behavior, rate of passage and rumen microbial population.

Example Re-ranking for RFI

Test Diet Forage		Test Diet Grain
Top 1/3 RFI		
Middle 1/3 RFI		
Bottom 1/3 RFI		Bottom 1/3



The top 1/3 of RFI tested animals on a forage diet may become the middle 1/3 of RFI tested animals on a grain diet and vice versa.

Research on Repeatability of RFI

Preliminary data from the Lacombe Research Centre, Canada, also confirms the moderate to strong repeatability of RFI over different stages of the animal's life. Replacement heifers identified as -RFI and +RFI when they were 8 to 12 months of age and fed a 90:10 percent barley silage and barley grain diet (as fed; -0.373 vs. 0.365 kg DM/day) were also -RFI and +RFI when measured again as 4 to 7 year old cows and fed a 70:30 percent grass hay and barley straw cube diet (as fed; -0.375 vs. 0.459 kg DM/day).

These results indicate that RFI is consistent across different stages of an animal's life, although there may be a need for different test criteria (e.g., forage vs. grain-based diets) when selecting terminal and maternal bulls. Breed types destined for maternal purposes should be tested on forage diets whereas those breed types designed for terminal sire purposes should be tested on grain-based diets.

RFI seems to be consistent across different stages of an animal's life.

Example — **Breed Type and Feeding Conditions**

Breed Type		Best Suited to Feeding Conditions
Maternal breeds	→	Forages
Terminal breeds	→	Grain or concentrate based

The most accurate test results for RFI are when feeding conditions reflect how cattle will be managed after the test. Grazing cattle are tested with forages, and feedlot cattle are tested with grains.

Body Size and Carcass Traits

RFI adjusted for final off-test backfat thickness is not related to pre- and post-weaning growth, body size, slaughter weight and carcass traits in beef cattle, and the phenotypic and genetic correlations are near zero. Experiments have shown no difference in carcass weight, dressing percentage or marbling grade between cattle of positive and negative RFI values.

Australian Research Study

In an Australian study, the muscle of efficient RFI (unadjusted for backfat) animals was found to be slightly leaner and also have slightly more calpastatin than inefficient steers which may negatively affect meat tenderness. Tenderness is being monitored in efficient animals to see if these results are repeatable in other cattle populations.

There are no differences in carcass weight, dressing percentage or marbling grade between cattle with positive and negative RFI values.

RFI is moderately to highly correlated with feed intake and feed conversion ratio (FCR). This implies that selection for -RFI will decrease feed intake at equal levels of body weight, growth and body fatness, and will improve feed-to-gain ratio in feeder cattle and growing replacement heifers.

Methane Emissions and Manure Production

Low RFI cattle have lower methane emissions than high RFI cattle.

The fact that efficient cattle have decreased feed intake at equal levels of body weight, growth and body fatness also implies that selection for low RFI will decrease methane (CH^4) emissions (g/animal/day) because methane emissions are proportional to feed intake. Generally, the higher the DMI, the higher the methane emissions. These estimated reductions in methane emissions of 9 to 12 percent also coincide with a 15 to 17 percent reduction in manure production. Improvements to feed efficiency will influence the carbon footprint of cattle, making beef more sustainable.

Alberta Research

After 25 years of selection for -RFI in an Alberta simulation model, the efficient 120-cow beef herd had lower GHG emissions by 101 t CO^2e per year or 0.844 t CO^2e per cow per year compared with the average 120-cow herd. In addition, the carbon footprint of the efficient herd was 14 percent lower than that of the cow herd not selected for RFI (19.82 vs. 23.06 kg CO^2e/kg carcass beef) and the total farm area decreased by 13 percent. These estimates of GHG reduction are conservative as improved DM digestibility in -RFI cattle and improved accuracy and rate of genetic change resulting from genomic enhanced breeding values were not considered. (Basarab et al. 2013)

Feeding Behaviors and Temperament

Inefficient (+RFI) cattle use more energy and may be more prone to stress.

Feeding behaviors that are collected as part of the RFI test suggest that inefficient (+RFI) cattle use about 5 percent more energy in feed related activities and possibly spend less time ruminating. They may also be more prone to stress since they also visit the feed bunks 9 to 22 percent more often each day and have more feeding during the night periods. Inefficient cattle may also be less docile and more nervous than efficient cattle.

Body Condition and Adaptability

In cold weather, -RFI (efficient) cows actually maintain themselves in better body condition score with no differences in productivity compared with their +RFI herd mates.

Dams that produced -RFI progeny consistently had 2-3 mm more back fat thickness, on average, over the 12th and 13th ribs and lost less weight during early lactation (pre-calving to pre-breeding) than mothers that produced +RFI progeny.

Efficient cows (-RFI) maintain better body condition in cold weather and lost less weight during lactation than inefficient cows.

In addition, -RFI (efficient) heifers calving for the first time had lower calf deaths within 30 days of birth than +RFI (inefficient) heifers. Lower calf death loss suggests that the improved early life survival of calves from -RFI mothers may be due to their improved feed efficiency resulting from more available nutrients and a better uterine environment compared with +RFI mothers.

Research Study from Lacombe

Recent research from the Lacombe Research Centre confirms these findings in that -RFI cows gained more body fat and body weight than +RFI cows when both groups swath grazed forages for the first time during Canadian winters where night time temperatures dropped below -20°C and animals grazed through the snow from November to March. Previous to this, both -RFI and +RFI young cows had been wintered together in smaller holding areas and fed barley silage to meet their nutritional requirements.

Even though efficient cattle have been documented to spend less time feeding and visit the feed bunks fewer times resulting in lower feed intake compared to feed efficient cattle when bunk fed in an RFI test, this does not mean that -RFI animals cannot compete or acquire forages during extensive grazing. Instead it may imply that efficient animals are more adaptable and less susceptible to stress than +RFI or inefficient animals.

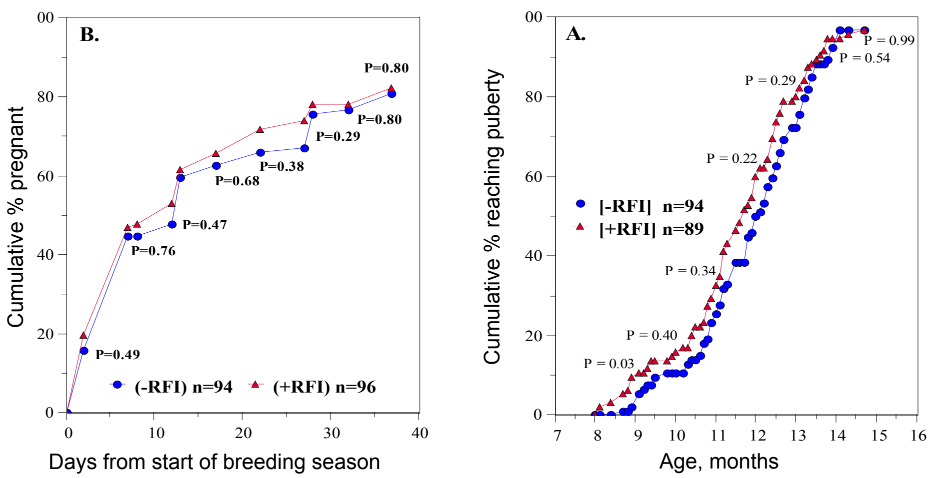
Fertility and Productivity

Fertility and productivity of efficient and inefficient cows seem similar in most cases.

The relationships of RFI on fertility and productivity in heifers and cows have recently been reviewed showing that -RFI and +RFI cows and heifers were similar in culling, pregnancy, calving and weaning rate, calving pattern and kilogram of calf weaned per mating opportunity (in both Canadian and Australian data). However, -RFI (efficient) cows calved 5-6 days later in the year than +RFI (inefficient) cows. Recent research has shown that heifer pregnancy rates in -RFI cattle can be 3 to 5 percent lower than +RFI heifers but these differences are not detectable in second and older calvers. When RFI was adjusted for body fatness (final off-test backfat thickness; RFI fat) no differences were observed in percentage of -RFI fat and +RFI fat heifers reaching puberty by 10, 11, 12, 13, 14 or 15 months of age nor in the percentage of calves born by day 28 of the calving season. Calving difficulty, age at first calving, calf birth weight, calf pre-weaning ADG, calf actual and 200-day weaning weight and heifer productivity, expressed as kg calf weaned per heifer exposed to breeding, were also similar between -RFI and +RFI heifers.

Figure 4.3 Comparison of -RFI and +RFI Heifers shows how -RFI (efficient) heifers appear to reach puberty later and get pregnant later in the breeding season compared to +RFI (inefficient) heifers. However, this small difference is likely a feature of the RFI testing procedure itself. Heifers reaching puberty near the start of the test period may actually have greater energy expenditures (5 percent greater) because they are cycling throughout the test due to their sexual development and greater activity compared to heifers that reach puberty near the end of an RFI test. So, this explains why they may breed and calve somewhat later. It may be possible to test older heifers or feed MGA (melengestrol acetate for suppression of estrus) during an RFI test to avoid these issues. What is important is that all the heifers reached puberty by 15 months of age (see Figure A) and all heifers were pregnant before 40 days of a breeding season. Both of these are suitable management targets.

Figure 4.3 Comparison of -RFI and +RFI Heifers (pregnancy rates and months to puberty)



A. Levels of significance are given for cumulative percent of heifers reaching puberty by 9, 10, 11, 12, 13, 14 and 15 months of age. B. Levels of significance are given for cumulative percent heifers pregnant by 2, 7, 12, 17, 22, 27, 32 and 37 days of the breeding season. (Basarab et al. 2011 Can. J. Anim. Sci.).

Both +RFI and -RFI heifers reached puberty by 15 months of age and were pregnant by day 40 of the breeding season.

Bull Fertility

Fertility of young bulls, as measured by scrotal circumference, breeding soundness evaluation, calves born per sire and semen characteristics, has been unrelated to RFI, although several weak associations have been observed with sperm morphology and motility. What this suggests is that perhaps the efficient -RFI bulls are younger and have less developed sperm. These observations may also reflect the need to adjust RFI for off-test ultrasound backfat thickness and feeding behaviors in an effort to prevent the selection for later maturing bulls.

Fertility of young bulls seems to be unrelated to RFI.

University of Alberta Research

In a study at the University of Alberta, the Kinsella herd showed there was no difference in the number of calves sired by -RFI bulls compared to +RFI bulls. It is important to not interpret poor sperm morphology with infertility since libido, in addition to other aspects of a breeding soundness evaluation, is important to ensure any bull, regardless of RFI status, is capable of breeding a cow herd.

All bulls, including RFI tested bulls, should pass breeding soundness evaluations before being sold as breeding animals.

Conclusion

You should now have identified your own breeding goals and some strategies for selecting desirable traits. Before you move on to the next module, make sure you clearly understand the difference between RFI and feed:gain and the effects of selecting for RFI on other traits.

In summary, you should now understand that there are economic and environmental benefits of using the concepts of RFI in your selection index for beef cattle.

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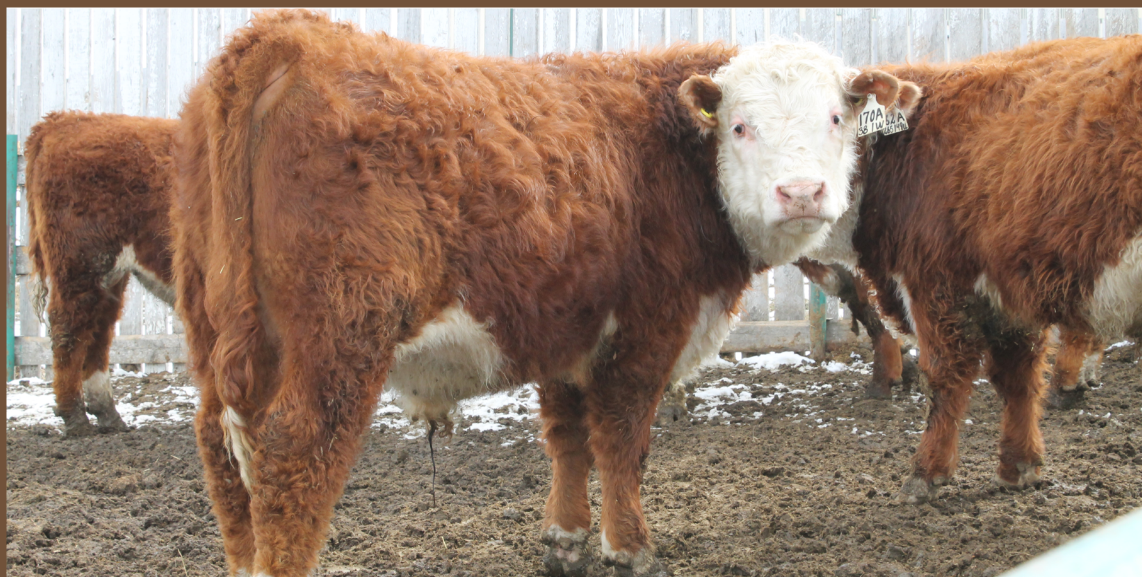
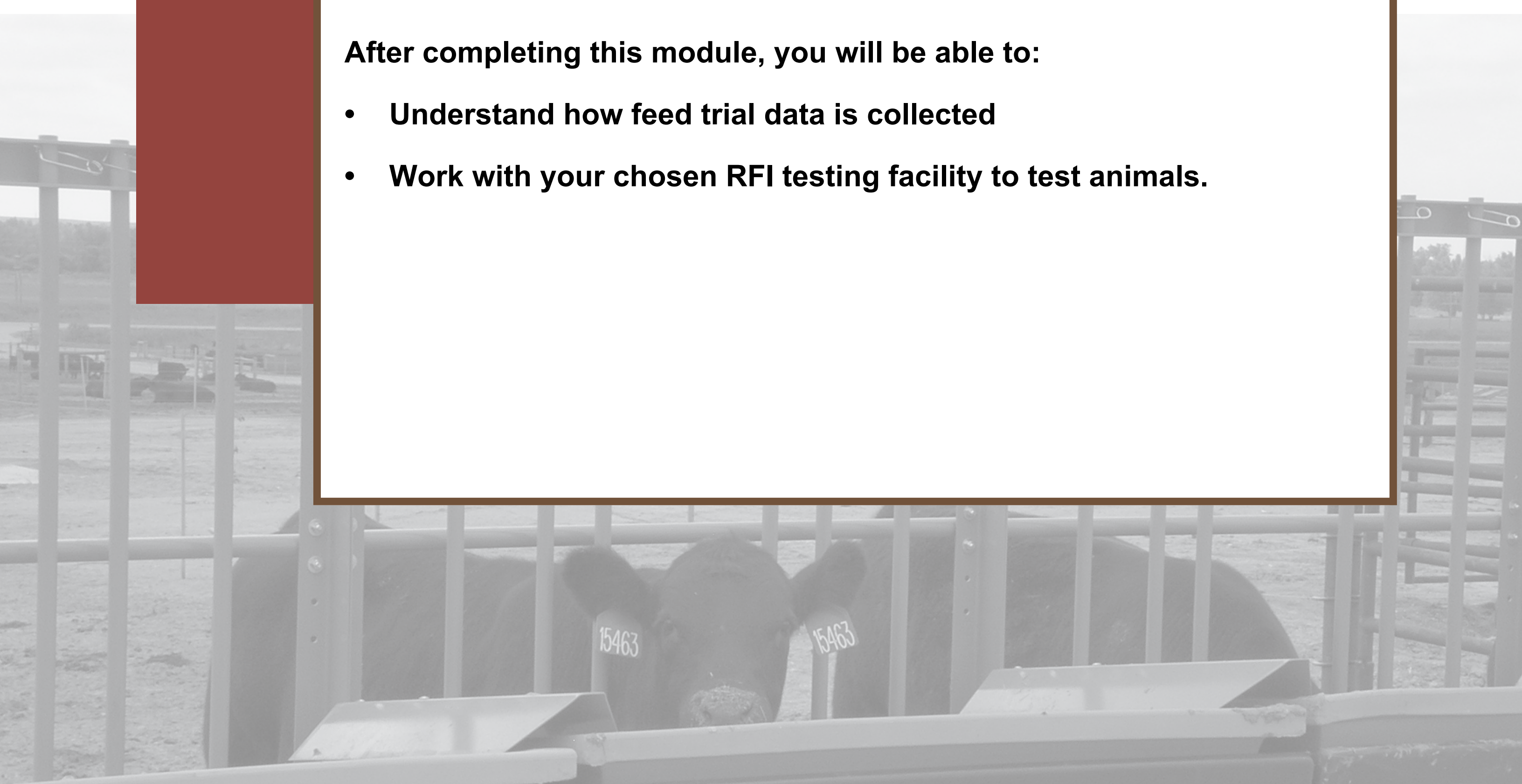


Collecting Accurate Data

After completing this module, you will be able to:

- **Understand how feed trial data is collected**
- **Work with your chosen RFI testing facility to test animals.**



Introduction

Early research to collect individual feed intake data was often expensive and laborious to measure and primarily restricted to university research. Results were often unreliable because animals were restricted to individual crates which affected their natural social behaviors resulting in unnatural feed consumption patterns that lead to faulty efficiency measures.

In 2000, a Canadian engineering company developed the GrowSafe Feed Intake and Behavioural Measurement System (GrowSafe). While this is not the only system capable of collecting individual feed intake from cattle, it has become widely used on a global scale. Every animal is equipped with an electronic radio frequency identification (RFID) ear tag. This "smart name tag" uniquely identifies each animal. An RFID-equipped trough is suspended on two load cells that measure with 10 gram resolution. The tag and trough measure feed disappearance every second. The system can be used outdoors in any environment. This system runs continuously and does not require any specialized feeding equipment or labor. Therefore, the animal's normal feeding behavior is not altered by human interaction nor is an animal restricted to what bunk can be utilized.

For a list of other systems, refer to Module 10-5.

With this system, accurate measures of the amount of feed an individual animal consumes on a daily basis in a commercial environment is possible in order to compare with the animal's growth performance to determine efficiency.

It is now possible to collect feed intake data that is accurate and affordable.

While each country may have a slightly different genetic improvement system, like "BREEDPLAN" in Australia http://breedplan.une.edu.au/tips/BREEDPLAN%20-%20The%20Traits%20Explained.pdf which currently has two EBVs for RFI, not all countries have a national beef breed improvement organization to search out standards.

To enable the beef industry to select for improved feed efficiency, regardless of location, testing procedures must be accurately and consistently measured over a standard test period. In order for a facility to become an accredited testing facility they must ensure the quality and consistency of their data are of the highest standards.

Canadian Testing Standards

The following sections outline the process to test an animal for feed efficiency using the GrowSafe Feed Efficiency Test.

GrowSafe Feed Efficiency Test Standard Operating Procedure (SOP)

(November 2010, J. Basarab and S. Johnson, ARD)

Prior To Test

Before you can test an animal for feed efficiency you need to take several steps to get ready for the test.

1. The GrowSafe System needs to be calibrated following recommended procedure as outlined in the manual given for your specific GrowSafe System. If you have any questions, contact GrowSafe.
2. Woodchips or wood shavings must be used as bedding to avoid animals consuming feed that is not detected. Occasionally straw bedding can be used when the ambient temperature drops below -20^{o}C and there is wind and snow. The data collected during this time should be examined carefully and removed from the calculation of average dry matter intake (DMI) and residual feed intake (RFI).
3. It is necessary to schedule in a certified ultrasound technician since it is known that RFI is slightly related to body composition. The best is to measure ultrasound body composition at the beginning and end of test, but one measurement at the end will also work. Calculation of RFI should include an RFI value unadjusted and adjusted for ultrasound backfat thickness.
4. Pre-test information on individual animals must include animal identification (RFID, visual tag number), breed or breed cross, actual birth date, and dam breed and age. Individual animal identification (e.g., registration number) should be easily compatible with other databases and unique (BIF 2010).
5. The GrowSafe System uses a half duplex RFID transponder button to record the animal's presence at the feeding stations. Most animals coming from cattle producers are tagged with a full duplex RFID transponder button due to their lower cost. Full duplex transponders will not be detected by the GrowSafe System. Since it is illegal to remove Canadian Cattle Identification Agency (CCIA) RFID transponders from livestock, an additional half duplex RFID transponder must be attached to the opposite ear. Placing the transponder on the same ear in close proximity to the full duplex transponder may cause poor performance in both transponders. The half duplex transponders must be removed at the end of the feed intake test period.

6. In order to acclimate to the testing facility, a pre-conditioning or warm up period of 21 to 28 days must be incorporated into the test calendar. During this period, animals should adapt to the test facility and the final test diet. Daily individual feed intake records collected during the pre-conditioning period or when animals are consuming transitional diets cannot readily be used in the computation of daily feed intake. Transitional diets are those that differ from the test diet (BIF).
7. The age at which an animal begins a feed intake test should be after weaning but not be less than 240 days. Within a feeding contemporary group, animals should have start of test ages within a 60 day range. Feed intake measurement on test should be completed before an animal reaches 390 days of age (BIF 2010).

GrowSafe Test Timeline

Research has demonstrated that a minimum of a 70 day test period following a 21 to 28 day adjustment period is required to accurately compute average daily gain for individual animals (Wang et al. 2006). Live weights are recommended to be recorded at equally spaced intervals. In research programs, live weights are often recorded at 2 week intervals. In central bull test facilities, initial and final weights are regularly estimated as the average of two live weights taken on consecutive days at the beginning and end of the test, respectively. In order to reduce measurement error, serial weighing is likely to result in the most accurate estimates of average daily gain, as long as a minimum of 5 to 6 weights are recorded at nearly equally spaced intervals over the test period. For a 70 day test, therefore, biweekly weight measurement is recommend, whereas for a 112 day test, recording live weight at 28 day intervals is recommended. Weigh dates must also be recorded to enable the computation of average daily gain (ADG) on test. On test ADG is computed as the linear slope from the regression of live weight on test day. Linear regressions for individual animals should have r^2 values equal to or greater than 0.95 (BIF 2010). Re-examine growth curves and health records of animals whose r^2 value is less than 0.95. If the animal was treated for sickness and this correlates to poor growth performance, remove the animal's data from further calculations. If a body for an animal is determined to be in error, remove the weight and re-calculate the r^2, slope (ADG) and y-intercept (initial body weight) for that animal.

You need to be prepared for a 70 day test period following a 21 to 28 day adjustment period or a total of around 100 days to complete the test.

FI Test, Day 0: At the end of the adjustment period, cattle will be weighed and measured for ultrasound backfat (BF), ribeye area (REA) and marbling (MAR) and fed the final test ration.

FI Test, Day 1: Record body weight and, if required, collect blood sample(s) in the appropriate vacutainer tubes (e.g., EDTA tubes for DNA).

FI Test, Day 14: Record WT only

FI Test, Day 28: Record WT only

FI Test, Day 42: Record WT only

FI Test, Day 56: Record WT only

FI Test, Day 70: Record WT only

FI Test, Day 84: Record WT only

FI Test, Day 85: Record WT, ultrasound BF, REA and MAR.

End of NFE testing

During GrowSafe Test

During the GrowSafe testing period, you will be required to conduct some daily and weekly checks.

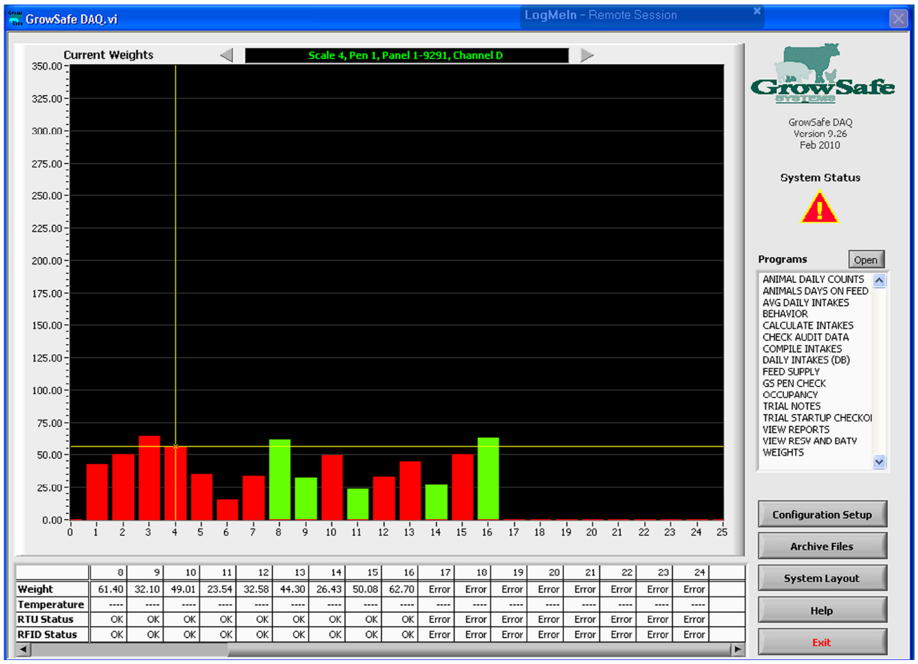
To ensure that the GrowSafe system is operating properly, the following procedures should be conducted once a week. It is especially important to check the following screens on a daily basis: Audit Data and Compile Intakes.

All problems/issues need to be logged for reference. Ensure that details are recorded for all sick/dead animals, treatments, lost/replaced RFID tags, extreme weather conditions, or if the system is down, for any reason, for an extended period of time.

1. On the main GrowSafe screen, ensure that ‘RTU Status’ and ‘RFID Status’ for each bunk displays ‘OK.’

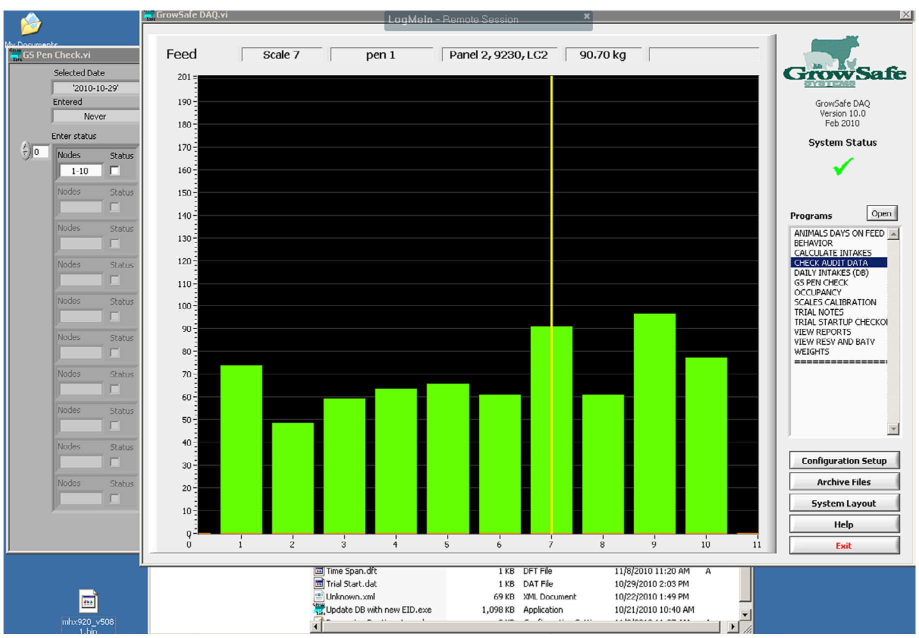
    a. If any of the bunks do not say ‘OK’ click on the ‘Configuration Setup’ button. On the Configuration Setup Screen, click on the ‘Status’ button (in the middle of the screen on the right hand side). On the RTU Status Screen, if any of the bunks display ‘Skipped’ in the Error Source column, or if any of the bunks have a red (instead of a green) square on the left hand side, click the ‘Unskip’ button. If all of the bunks (all rows) then have a green square on the left hand side and there are no messages in the Error Source column, the issue should be resolved. Click ‘Exit’ on the RTU Status Screen. Click ‘Save’ and then ‘Exit’ on the Configuration Setup Screen. All bunks should then display ‘OK’ in the ‘RTU Status’ and the ‘RFID Status’ rows.

    b. If the above steps do not resolve the issue you may need to contact GrowSafe for assistance.



In the above image we can see the error system under ‘System Status’ and see that bunks 17 through 24 have ERROR list under RTU and RFID. This indicates a problem.

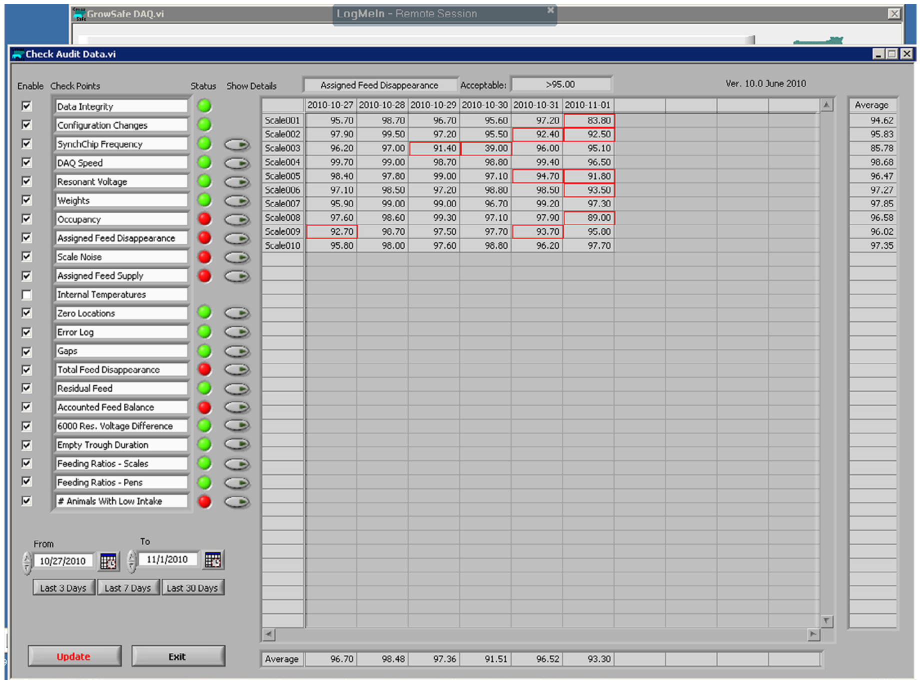
Make sure you log any errors or problems.



This image shows no error message and therefore means that all RTU and RFID are in good working order.

2. On the main GrowSafe screen, select ‘Check Audit Data’ under ‘Programs.’ Click ‘Open.’ Set the dates of interest and click ‘Update.’ Click on the arrow to the right of a green or red dot to obtain details. Click ‘Show Details’ for the ‘Assigned Feed Disappearance.’ All bunks should have an Assigned Feed Disappearance value of 95 percent or greater.

If any of the bunks are outlined in red or show less than 95 percent assigned feed disappearance, further investigation should be done to determine why (see details for 'Compile Intakes' screen). Data for this day may not be valid. Record details.



3. On the main GrowSafe screen, select 'Compile Intakes' under 'Programs.' Click 'Open.' In the top right hand corner select the date of interest. Click 'Other' to select the bunk of interest and click 'OK.' Click 'Next' or 'Previous' to move between bunks. For each bunk, in general, the screen should depict a vertical line at the time of feed delivery, followed by a steady overall decline in weight, indicating that feed is disappearing due to animals feeding. During animal feeding, the weight will spike up each time an animal sticks its head in the bunk and presses down on the bunk; however, the baseline should show an overall decline in weight. Ensure that the 'Weight filter' is turned off (at the bottom left hand side of screen). Ensure that a colored dot is depicted at each weight spike. The colored dot indicates that an RFID was detected (each different color indicates a different RFID), and that particular amount of feed disappearance will be allocated to that particular RFID. Use the buttons on the bottom left hand side of the screen to zoom in and out, and to navigate throughout the day.

   a. If feed is disappearing without an RFID being detected, action should be taken to determine why, particularly if this occurs several times throughout the day. If this occurs immediately after feeding, but does not occur later on in the day, this may indicate that the bunk was overfilled. Ensure that feed is delivered evenly to all bunks. If feed is delivered evenly to all bunks but overfilling is still occurring, feed may have to be delivered twice a day to prevent overfilling of bunks. Record details.

b. If feed is disappearing, with no RFID detected, at different times throughout the day at several different bunks, this likely indicates that an RFID tag for one of the animals is missing or malfunctioning. By viewing the ‘Daily Intakes’ screen, determine if an animal has a much lower than normal feed intake for that day. The RFID tag may need to be replaced for that animal. Record details.

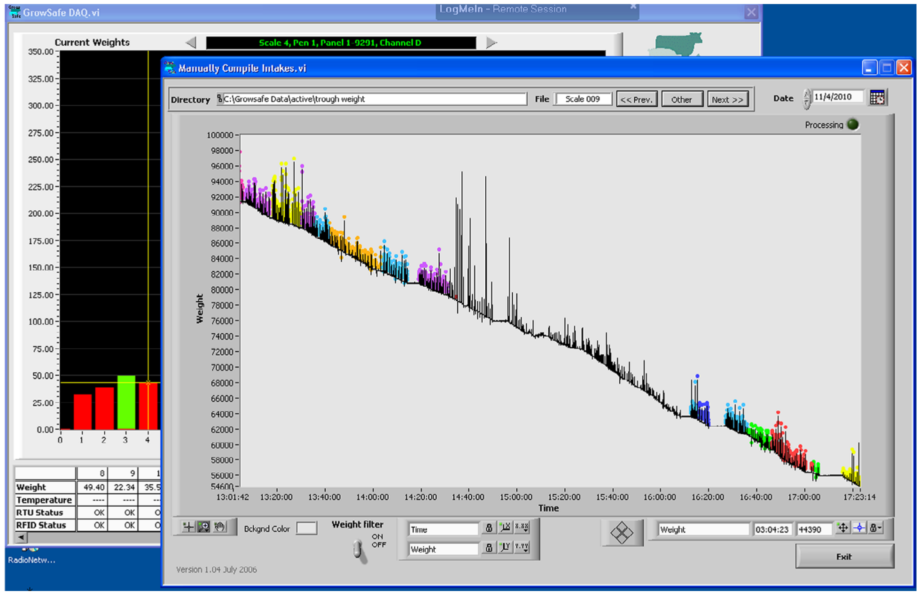
c. If feed is disappearing with no RFID detected for an extended period of time at one particular bunk, check to see if the pigtail for that bunk is properly plugged into the RTU. If the pigtail is properly plugged into the RTU, the pigtail may be broken and need to be replaced. Contact GrowSafe for assistance. Record details.

d. If a bunk shows a completely straight horizontal line, with no vertical fluctuations, even when zoomed in closely, and colored dots are depicted during that time, there is most likely a problem. Check to ensure that the bunk is properly positioned on the load cells and hanging freely. If that is not the problem, contact GrowSafe for troubleshooting assistance. Record details.

e. If all bunks show a completely straight horizontal line at the same time, with no vertical fluctuations, even when zoomed in closely, and colored dots are depicted during that time, this indicates that power was reaching the system but weight data was not being recorded from the scales. This could happen if there was a power outage or the computer was re-booted, and the ‘Write Scale Data’ on the main screen is set to 5 or 10 minutes, resulting in scale data not being recorded for up to 10 minutes prior to the power outage or re-boot. Ensure that the ‘Write Scale Data’ is switched to ‘Immediately’ before the computer is shut down or re-booted. Record details.

f. If all bunks show a completely straight horizontal line at the same time, with no vertical fluctuations, even when zoomed in closely, and no colored dots are depicted during that time, this likely indicates that power was not reaching the system. Check to see if there was a power outage at that time or if the GrowSafe system was unplugged. If there was a power outage and the system is plugged into a backup power supply (which is recommended), check to see why the backup power source did not function properly. Record details.

g. If the baseline weight for a bunk periodically increases slightly without feed being added to the bunk, check to ensure that the guards covering the load cells and sides of the bunk are not pushing down on the bunk. Heavy rain, snowfall, strong wind or birds landing on the bunks can also cause weight fluctuations. If none of these issues are the cause, contact GrowSafe for assistance. Record details.



This picture provides a good example of a bunk not detecting EID. You can see that around 2:30pm on this day, the bunk stopped reading EIDs as there is no detection dots above the weight line. This was caused by a pigtail coming unplugged.

4. On the main GrowSafe screen under ‘Program’, click on ‘Animal Daily Counts’ and click ‘Open.’ On the Animal Daily Counts screen, in the bottom left hand corner, select the ‘From’ and ‘To’ dates. Click ‘Update.’ Ensure that the number displayed for each pen on each day corresponds to the total number of animals in the pen.

    a. If the number displayed for a pen does not match the total number of animals in that pen for a particular day, check to see if one of the animals was sick and did not eat that day or an animal died or was removed from the pen. If an animal was not sick, dead or removed from the pen, or if the total number displayed for a pen does not match the total number of animals in that pen for two or more consecutive days, check to see if the RFID tag for one of the animals is broken or missing. That animal’s RFID tag may need to be replaced.

    b. For any of the above cases, the particular animal that did not eat can be determined by viewing the ‘Behavior’ (step #5) or ‘Daily Intakes’ (step #8) screens.

5. On the main GrowSafe screen, select ‘Behavior’ under ‘Programs.’ Click ‘Open.’ Select the pen of interest and the animal of interest. Ensure that the correct dates of interest are specified in the ‘From’ and ‘To’ boxes. Click ‘Next’ or ‘Previous’ to move between RFID tags. Click ‘Other’ to select a specific RFID tag. Ensure that red dots are periodically dispersed throughout the screen for each RFID.

a. If no red dots are depicted for all bunks, for all animals, for an extended period of time, it likely indicates that there was no power supply to the system during that time. Check to see if there was a power outage at that time or if the GrowSafe System was unplugged. If there was a power outage and the system is plugged into a backup power supply (which is recommended), check to see why the backup power source did not function properly. Record details. Data for this day may not be valid.

b. If no red dots are depicted for one animal for an extended period of time, check to see if the animal was sick, removed from the pen, or died. If the animal was not sick, removed from the pen, or dead, check to see if the animal's RFID tag is malfunctioning or missing. The RFID tag may need to be replaced for that animal. Poor weather conditions can also contribute to lower than normal activity at the feed bunks. Ensure that poor weather conditions, lost or replaced RFID tags, animal sickness and all treatments are recorded.

If any problems are found, contact either GrowSafe at 403-912-1879 or John Basarab at 403-782-8032.

Feed samples of the total mixed ration (TMR) should be collected weekly and pooled monthly. Follow the procedure below:

Feed Sampling

Sampling procedure: several random handfuls of material should be taken of the TMR (sample should be about the size of a soccer ball) and placed in a plastic bag, labeled with sample type and date. If a scale is available, take a wet sample weight immediately after sample is collected. If no scale is available, samples are to be put in the freezer and stored at -25^{o}C until analysis.

Weekly samples will be pooled at the end of the study to create one composite sample for each month. If wet weight has not been taken, do so before pooling samples. Thaw frozen weekly samples, select ¼ of each bag and place together into one composite bag. Seal tightly, attach label and refreeze. A representative sample refers to several random handfuls of material that represent the TMR. All samples will then be collected at the end of test, wet weights recorded and dried in a 80°C drier, dry weight recorded, and sent for analysis of acid detergent fiber (ADF), neutral detergent fiber (NDF) and crude protein (CP). Total digestible nutrients (TDN), digestible energy (DE), net energy for maintenance (NEm) and/or net energy for gain (NEg) will be calculated using equations acceptable to the feed analysis laboratory or equations found to be acceptable by your consulting ruminant nutritionist.

You will need to collect weekly feed samples.

Any animals treated or pulled from the pen for any reason during the test must have the following records:

Date:
Dangle Tag color and Number:
E.I.D number:
Observations: (lame, runny nose, etc.)
Weight:
Temp:
Treatment performed, type of medication and amount given, etc:

During the winter, feed left over in the bottom of tubs can freeze and cause a buildup. Check tubs for excess buildup weekly and clean out if necessary.

End Of Test

At the end of the testing period, data must be validated according to a set procedure.

1. All feed samples collected and sent off to lab.
2. GrowSafe.mdb file available for data analysis.
3. Data must be validated as per requirements below:
   - All bunks must have an assigned feed disappearance (AFD) of no less than 90 percent for any day and the average of all bunks in a day must be greater than 95 percent. Omit feed intake for all bunks in a pen for that day where this condition is not met.
   - For electronic intake data recording systems, data auditing functions monitor the quality of intake records, and are used to judge the suitability of intake data prior to further analyses. Feed delivered to animals and that recorded by the system as consumed should not differ by more than 5 percent. Technicians should utilize all data integrity features available on individual feed intake recording systems. Once daily dry matter intake is computed for individual animals, simple correlations among DMI, ADG, live weight, RFI and expected feed intake (EFI) should be computed. Correlations that are not at least moderate (r=0.4 to 0.6) and positive indicate suspect data. Researchers and test managers are encouraged to consult with experts to conduct further data auditing to ensure the highest possible integrity of test data before proceeding with further analyses. Additionally, for tests where residual feed intake (RFI) or other measures of efficiency will be computed, the correlations of such measures with their components should be computed and compared to published values. Means and standard deviations of DMI, ADG, body weight and RFI by contemporary group are also useful as low group variation in weight and/or ADG may explain low correlations among DMI, ADG and body weight (BIF 2010). The standard deviation for RFI usually varies between 0.40 and 0.80 kg DM/day, with a mean of 0.60 kg DM/day for young growing animals; however, the standard deviation can increase to a higher level when cows are being fed on a high roughage diet.

The coefficient of determination (r^2) for expected feed intake should be greater than 0.40. The average of 30 feed intake tests on over 3,200 animal conducted in Alberta was 66.4 percent (Basarab, personnel communication, 2010).

A Third Party Audit of Feed Intake Data (example below)

Assessment of Feed Intake Data Used to Calculate Residual Feed Intake

1. Location ______________
2. Animal type ______________
3. Test period ______________
4. Number of animals ______________
5. Total days on test ______________
6. Number of GrowSafe feeding stations _______
7. Days deleted due to system malfunction, bad weather, etc. _______
8. Days used to calculate RFI _______
9. Percentage of “feed accounted for” on days used to calculate RFI - mean _____%
10. -SD _______
11. -MIN _____%
12. Total number of feeding-station-days _______
13. Number of feeding station-days where “feed accounted for” was < 94% _______
14. Percentage of feeding-station-days where “feed accounted for” was < 94% _____%
15. Partial correlation coefficient between DMI and metabolic weight _______
16. Partial correlation coefficient between DMI and average daily gain _______
17. Partial correlation coefficient between DMI and expected feed intake _______
18. Coefficient of determination for Expected Feed Intake (EFI) equation _____%
    EFI = a0 + β0 + β1 (ADG) + β2 (MWT) + β3 (FAT) + RFI, where β0 is the feeding contemporary group

OVERALL ASSESSMENT OF THE FEED INTAKE DATA – "GOOD"

RESIDUAL FEED INTAKE VALUES CALCULATED BY:
Date: _______________,

FEED INTAKE DATA AUDITED BY:
Date: _______________,

Signature: _____________________________

Note: RFI and feed to gain ratios are questionable if the coefficient of determination for EFI is below 30 percent and the overall mean of "FEED ACCOUNTED FOR BY GROWSAFE SYSTEM" is below 95 percent.

Conclusion

You should now know how feed trial data is collected and understand the process to test an animal for feed efficiency. This should give you the ability to work with a testing facility in order to test your own animals.

In the next module, you learn the costs and steps to get RFI testing completed.

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6

The Value of the RFI Test

After completing this module, you will be able to:

- **Describe the costs of a typical residual feed intake (RFI) test**
- **List the time and conditions required to run an RFI test**
- **Explain the standard calculations required to rank cattle**
- **Outline the reason you may need assistance from trained people to ensure accuracy and reliability of data.**

Introduction

The first five modules provided you with the motivation to improve feed efficiency using residual feed intake (RFI) and the requirements to move in this direction.

This module provides you with details on costs and steps to get the phenotype testing completed. It also provides you with more information on the calculations made by those trained in testing.

Costs of Testing for RFI

Many western Canadian feedlots, bull test stations, universities and Agriculture and Agri-Food Canada Research facilities have individual feed intake monitoring equipment, installed for their research programs. These are predominantly GrowSafe Systems technology (Airdrie, Alberta, Canada). Increasing interest in the trait of RFI has led to an increase in system installations around the world.

The most commonly RFI tested animal is the breeding bull, but the test can be done with any type of animal (purebred or crossbred heifers, cows or feeder calves). However, you must consider the following for accurate results of the genetic evaluations: good contemporary groups, feed delivery system is maintained and working well, all animals are allowed the same access to the feed bunks where the data is collected, good bunk management and manager/operator reviews daily feed logs to ensure all animals are able to access feed.

More details on testing procedures can be found in Module 10-19.

As a beef cattle producer looking to source tested RFI cattle for your herd, you need to be aware of the costs. Typical costs to have cattle tested using these facilities with individual feed intake monitoring technology include:

- Feed and bedding costs
- Yardage costs
- Equipment rental fees
- Processing fees for backfat ultrasound and live weights
- Breeding soundness evaluations for bulls.

Make sure you understand the total cost of having your cattle tested.

Cost of Standard Bull Test

If you breed purebred cattle and want to measure feed efficiency in your superior conformation and performance bull calves, a standard bull test for 20 head costs about $250 to $350/head.

Cost of Bull Test for RFI

The bull test for RFI requires at least 70 days on the GrowSafe individual feed intake monitoring system in addition to approximately 3 weeks of adjustment on the final test ration. Costs, including feed and yardage, are estimated to be $450 to $550/head based on a 20 head minimum.

The difference of an RFI test over the standard bull test is about $150 to $250, depending on services provided during the test.

An RFI test offers two key advantages over a standard test:

- You identify the superior genetics of the feed efficient bulls to build more efficient cow herds
- Feed efficient (-RFI) bulls are likely to sell for a higher value compared to the feed inefficient bulls.

What the Research Tells Us

The Midland Bull Test Station in Columbus, Montana, which can test over 1200 bulls per year, collected data from their annual sales of RFI tested bulls over many years and found that bulls with -RFI scores brought up to $300 per head more than bulls with +RFI scores.

Sourcing RFI tested cattle for genetic improvement in your herd and culling the bottom 20 to 30 percent of your inefficient cattle will help you:

Sourcing RFI tested cattle can help you save costs, increase live animal value and build a sustainable herd.

- Save feed costs
- Increase live animal value
- Build a more sustainable cattle population.

RFI/NFE Costs 2011 Example of fees based on twenty head						
	$/hd	#Head	Tested Days	Estimated Cost	My Costs	Comments
GS Head Days	$2.50	20	100	$5,000.00		
Yardage	$0.56	20	100	$1,120.00		
Ultrasound/hd	$11.00	20		$220.00		If unavailable then we can calculate RFI unadjusted for backfat
US Setup	$250.00	1		$250.00		
BSE Setup	$83.00	1		$83.00		Breeding Soundness Evaluation
BSE/head	$54.00	20		$1,080.00		
Bedding	$0.02	20		$4.00		As needed
Feed	$1.50	20	100	$3,000.00		
Health	$0.33	20	100	$660.00		
Weight Days	$3.00	20	6	$360.00		Based on two initial, 2 interim and 2 final weigh days
				$11,777.00		Total estimated cost
				$588.85		Average per head based on 20 head minimum
Regular bull test; $6,777.00 or $338.85/head						

(Adapted from W. Torres, Cattle and Feed Yards, Ltd., 2013)

Ranking Cattle for Feed Efficiency

Currently, the easiest way to select for feed efficiency (if you are not testing your own cattle) is to purchase feed efficient or negative RFI bulls to use on your cow herd. Typically RFI is measured in young cattle (7-10 months of age) in feedlot pens fitted with feeding stations designed to automatically monitor individual animal feed intake over a 70 day test following a three week adjustment to the test diet. Cattle are weighed before feeding on two consecutive days at the start and end of the test period and at approximately 14 to 28 day intervals. They are also measured for ultrasound backfat thickness (mm), ribeye area (cm^2) and marbling score at the start (optional) and end of the test period.

GrowSafe Systems Ltd., Airdrie, Alberta, Canada

The easiest way to select for feed efficiency is to purchase feed efficient bulls to use on your herd.

Calculations of RFI – the Practice and the Theory

The information below provides a brief description of the calculations. For a more detailed explanation refer to Module 10-21.

In order to avoid any short-term effects over an animal's growth period, like morbidity or nutritional restrictions, the growth of animals over a period of time is measured and modeled by linear regression.

Initial weight, ADG, mid-point weight (MIDWT) and final weight are calculated from the regression coefficients of each animal's growth curve. Daily feed intake is converted to total feed intake of each animal during the feeding period and then to total energy intake by multiplying total dry matter intake by determined gross energy of the metabolizable energy (ME) content of the diet fed. The ME content of the diet is determined from the acid detergent fiber (ADF %) content of the analysed feed samples (usually 3). Total energy intake is then divided by 10 to give total DM intake standardized to an energy density of 10 MJ ME/kg of DM. Total standardized feed intake (SFI) is then divided by the number of days on test to give average standardized daily feed intake (SFI, kg/day).

To calculate expected feed intake (EFI, kg DM/day), ADG (kg/day) and metabolic midpoint weight (MIDWT, kg 0.75) and final off test backfat thickness (mm) are used to model daily EFI.

Residual feed intake is then calculated as deviations of SFI from EFI (RFI=SFI-EFI). Animals with low or negative RFI values are more efficient than those with high or positive RFI values. When ME intake equals total ME requirements, the energy requirements of the animal are completely met.

Positive RFI

A positive RFI means that the animal requires more energy than what is estimated or is eating more to produce the same weight gain. This means the animal may have a lower efficiency of use of the feed consumed or a higher maintenance requirement.

Negative RFI

When RFI is negative, it means that the animal either requires less energy than what is estimated, or it is eating less to produce the same weight gain. This means the animal has a higher efficiency of use of the feed consumed and/or a lower maintenance requirement.

In practice, you want animals that have a negative RFI which means the animal has a higher efficiency of use of the feed and lower maintenance requirement.

Conclusion

You should now have some idea of what it costs to test for RFI and upon what these costs are based. In the next module, you examine how to apply benefits of RFI into your herd, whether you have a purebred or commercial cow/calf or feedlot operation.

See the Resource Section for a list of locations with GrowSafe Systems individual intake monitoring technology.

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7

Apply Feed Efficiency Technology in Your Herd

After completing this module, you will be able to:

- **Determine if testing your own cattle and/or purchasing RFI tested cattle is how you can improve feed efficiency in your herd**
- **Calculate simplified estimated breeding values and expected progeny differences for RFI and compare the economics in terms of feed savings from progeny of different matings**
- **Calculate feed cost savings for a cow-calf operation or for a feeder/ backgrounding operation**
- **Compare other traits of importance, in addition to feed efficiency, in order to make mating decisions based on multi-trait selection using data including EPDs.**

Introduction

In Modules 5 and 6, you started to explore requirements to test feed efficiency with RFI and the associated costs.

This module will help you to apply feed efficiency technology to your own herd. It also means comparing other traits of importance in order to make breeding decisions based on multi-trait selection.

Cost Benefit Analysis of Residual Feed Intake (RFI)

There are benefits of feed efficiency, as defined by RFI, for many participants in the beef industry:

- Purebred or commercial cow-calf
- Backgrounding
- Feedlot
- Pasture beef operations.

This is because feed costs are a significant cost to all of the above participants. Profit drivers for the cow ranch and the feedlot are closely related.

Example

Factors Affecting Profitability in a Cow-Calf Operation

If you have a cow herd, you are concerned with how much cows eat, early season breeding, calf weaning weight and stayability.

Example

Factors Affecting Profitability in a Feedlot

The top factors affecting profitability of feedlot calves are related to feed to gain ratio which includes ADG and feed intake (43%), market or grid value (39%), carcass weight (18%) and animal health (1%).
(adapted from Lee Leachman, Leachman Cattle Co.)

Regardless of your operation, you should be just as concerned about feed efficiency as you are with the market price.

Progress made by genetic selection for RFI affects the feed to gain ratio of cattle in a desirable way.

Because RFI is moderately heritable (35-40%), you can make genetic progress by selecting for cattle with negative RFI who also have desirable growth, carcass merit, fertility and lifetime productivity. This means you get paid for the outputs of calf or yearling weight and/or meat yield, yet you save on feed costs, especially for your females back at the ranch. It's a win-win! You can produce efficient, productive cattle on fewer feed related resources. A further advantage is that those cattle with negative residual feed intake (-RFI) are known to produce less manure and have lower methane emissions. This makes them more environmentally sustainable.

All these production measures have economic value to the beef operation. This section provides examples of how to calculate the value of selecting for low RFI cattle. **Figure 7.1 Trends in Estimated Breeding Values for Residual Feed Intake (RFI)** compares the progress that has been made in reducing dry matter intake and the resulting feed costs throughout the 1990s at an Australian research centre. It shows the results of selection for feed efficient cattle by using RFI. The negative RFI (high efficiency cattle) have reduced their dry matter intake per day by close to 0.5 kg. This resulted in significant feed savings to the beef operation. However, given that producers have multi-trait breeding goals, the researchers assumed a reduction in feed intake of -0.08 kg DM/day (0.8%/year) in a 25-year simulation (compared to not selecting for RFI).

As each generation is selected for improved feed efficiency, the feed savings increase.

Doing the Math

As already discussed, response to selection is based on intensity of selection (i), accuracy of selection (r), genetic standard deviation (SD) and generation interval (L) or genetic change = (i x r x SD)/L. If we are selecting solely on an individual's own phenotype, then accuracy of selection is the square root of heritability or r = 0.63 assuming a heritability for RFI of 40 percent. If the genetic standard deviation (SD) for RFI = 0.63 and the RFI phenotype = -1 kg DM/day, then -1 x 0.63 x 0.63 = -0.40 kg DM per day is the "simplified Estimated Breeding Value" (EBV) for this individual animal.

If we mated this bull (EBV = -0.40) to an average group of cows (EBV = 0) not selected for RFI, then the expected progeny difference (EPD) would be (sire EBV for RFI + dam EBV for RFI)/2 or (-0.40 +0.00)/2 = -0.20 kg DM per day or a reduction in feed intake of 0.2 kg DM for this cross in generation 1. If we were to plot this across the entire herd and many generations, the annual rate of genetic response would be a reduction of 0.40 kg DM per day/5.0 years for generation interval or 0.08 kg DM per day.

This annual rate of genetic response is over-estimated, since cattle breeders will select for multiple traits or use multi-trait selection indices. When this is done, the annual rate of genetic response at the herd level is a reduction of about 0.02 kg DM per day.

What all of this tells you is that a reduction in intake of 0.02 kg DM per day in the cow herd would equate to feed cost savings, assuming a cow size of 1400 lb. (640 kg) eating 14.3 kg DM feed/day at a 2014 price of $0.12/kg DM. This average cow costs $626.34 to feed for the year compared to selecting for improved RFI resulting in feed costs of $625.46/hd/yr. A herd of 100 cows selected for RFI would save you $88 in feed costs over the first year with more savings after each generation. Obviously, if feed ingredient costs increase, these savings will be significantly more. As each generation is selected for improved feed efficiency, the feed savings will increase (compared to not selecting for RFI).

Improve Your Baseline

One of the criticisms of selecting for the trait of RFI is the small gains in economics directly related to feed costs. Over many years and with many cattle, feed savings are realized. A different perspective to take is to look at culling those animals with significantly poorer feed efficiency to improve your herd baseline or average.

Example **Culling the Bottom 15 Percent of Animals**

If you have 20 replacement heifers that have been RFI tested, you can cull the bottom or inefficient heifers to improve your herd.

Of the 20 heifers in this herd, the 3 most inefficient with the highest positive RFI values are +0.55, +0.37 and +0.28 kg DM/day. By culling these heifers, your baseline RFI will improve from 0 to -0.07 kg DM/d.

Heifer #	RFI	Heifer #	RFI
1	-0.02	11	+0.03
2	-0.30	12	+0.18
3	-0.08	13	+0.20
4	-0.10	14	**+0.28**
5	-0.15	15	**+0.37**
6	-0.22	16	**+0.55**
7	-0.06	17	+0.23
8	-0.47	18	+0.17
9	-0.51	19	+0.19
10	-0.43	20	+0.15

Average of 20 head = 0

Average of 17 head once poor RFI heifers are culled = -0.07

Your herd's RFI baseline, or average, can be improved by culling the inferior or most +RFI individuals.

Feed savings:

Assume 1000 lb. heifers eat 11.4 kg DM/day valued at $0.12/kg. This means each of these heifers costs $500/year to feed. By culling the bottom 15 percent for poor RFI, the change in feed of -0.07 kg DM/d amounts to a savings of $4/heifer/year in feed costs.

11.4 kg/d – 0.07 kg/d = 11.33 kg/d x 365 d x $0.12/kg = $496
($500 - $496 = $4 reduction in feed cost/heifer/year)

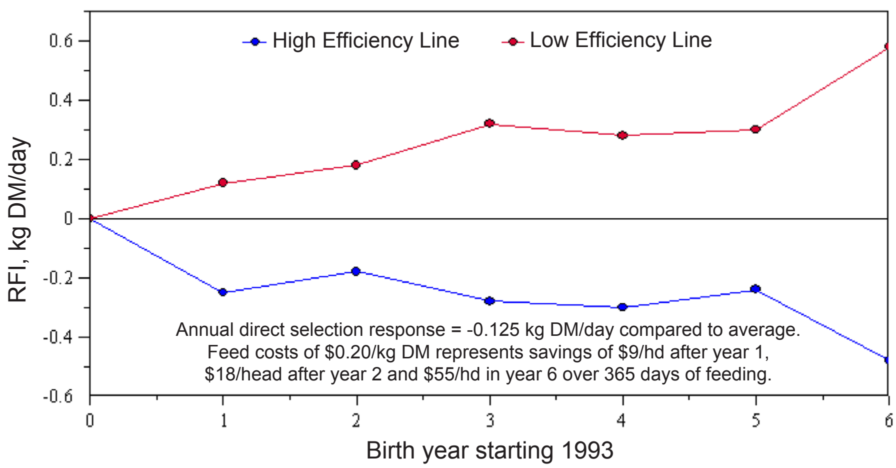
A herd of 100 heifers selected for RFI would cost $400/year less to feed compared to an average herd not selected for RFI where RFI=0.

You can continue to make progress in improving feed efficiency well into the future. Each generation improves after targeted selection for the trait. See Figure 7.1 below.

Figure 7.1 Trends in Estimated Breeding Values for Residual Feed Intake (RFI)

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

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



You do not have to give up average daily gain or growth performance for reduced feed intake.

Figure 7.1 above shows how selecting for RFI over 6 years realizes a reduction in feed intake of 0.5 kg DM/head/day for the high efficiency line compared to an average herd where RFI=0, and a reduction of 1 kg DM/head/year compared to the low efficiency line that was not selected for RFI where the average RFI=0.5. The difference in the feed intake from the low efficiency line to the high efficiency line is 1 kg DM/hd/year feed reduction (since the RFI range of +0.5 to -0.5 = 1).

Apply Feed Efficiency Technology in Your Cow-Calf Operation

Now it is time to see how feed efficiency technology can be applied in your own herd. This section covers the application of RFI to bulls, yearling replacement heifers, bred heifers, mature cows and feedlot cattle.

Feed Efficient Bulls

Let's start by looking at two different bulls—one with a negative RFI (feed efficient) and one with a positive RFI.

Bull A **Bull B**

Average cow herd RFI = 0

Bull A
RFI -1.45 lb. DM/day

EPDs (lb.)	CE	WW	Milk
	+0.9	+47.8	+26.8

Bull B
RFI +1.11 lb. DM/day

EPDs (lb.)	CE	WW	Milk
	+1.5	+48.9	+17.4

Bull A is feed efficient. He has a negative RFI (-1.45 lb. DM/day)

Compared to an average bull with RFI=0, Bull A will sire calves that eat less (as noted by the negative value) while Bull B will sire calves that eat more (as noted by the positive value) for their performance when mated to the average (not selected for RFI and thus RFI=0) group of cows. With simplified calculations for an estimated breeding value (EBV), you may expect the following.

Example **Bull A—Feed Efficient**

Bull A with an RFI = -1.45 lb. DM/day x 0.63 x 0.63 = -0.58 lb. DM/day.

If mated to RFI average cows of his same breed, cow RFI EBV=0.

Progeny are expected to perform at (-0.58 + 0)/2 = EPD of -0.29 lb. DM/head/day.

See "Doing the Math" on page 7-4 to see from where values are generated.

On a typical 2014 priced forage based backgrounding ration for 115 days, costing $0.065/lb./day or $0.14/kg/day DM basis, this set of calves saves you $2.24/head in feed.

Replacement heifers retained from this sire save you the $2.24/head during the backgrounding phase, plus an additional $7.12/head/year in feed. This means these heifers were $9.36/head cheaper to raise to first calving in feed costs alone compared to an animal with RFI=0.

Bull B is feed inefficient. He has a positive RFI (+1.11 lb. DM/day).

Example — Bull B—Feed Inefficient

Bull B with an RFI= +1.11 lb. DM/day will sire progeny with an expected RFI =+0.22 lb. DM/day if mated to RFI average cows of his same breed with EBVs for RFI=0. Feed for these calves will cost you $1.64/head for the backgrounding phase and an additional $5.22/head/year to raise to first calving. This means these heifers were $6.86/head more expensive to feed than an animal with an RFI=0.

Compared to Bull A, the replacement heifers of Bull B cost you $16.22/head more to feed from weaning to first calving.

Assumptions

The economic scenario assumes feed savings from using a -RFI bull on cows with RFI=0. Additional feed savings are possible by using feed efficient females or retaining heifers from the -RFI sires. Feed prices assume forages at $0.025/lb. and barley grain prices below $180/tonne. You would realize additional feed cost savings when feed prices increase.

Yearling Replacement Heifers

Remember, this is not about single trait selection for feed efficiency. You need to consider RFI as an additional trait with your other breeding goals.

As a start, you can select replacements based only on feed efficiency, but you should also include an assessment of their growth, conformation and fertility. As a breeder, if you have selected for feed efficient females, like a daughter from Bull A, and you mate her to a -RFI bull, you can make even more genetic progress in feed efficiency and save even more in feed costs.

Bull C

RFI = -1.06 lb. DM/day

EPDs	CE	WW	Milk
lb.	+1.1	+36.5	+21.8

Example: Bull C (Feed Efficient) Mated to Feed Efficient Heifer

Refer to page 7-4 for complete calculation. RFI accuracy of selection is based on a heritability of 40 percent so the square root $\sqrt{.40}$ = 0.63 x genetic standard deviation of RFI = 0.63 then .63 x .63 = 0.4 as reported below.

RFI= -1.06 x 0.4 heritability = -0.42 lb. DM/day.

Replacement heifer (purebred daughter of Bull A): actual RFI= -0.29 x 0.4 heritability = -0.12 lb. DM/day.

Progeny expected (average of the parents): -0.42 + -0.12 = -0.54/2 = EPD RFI -0.27 lb. DM/day.

This calf will save you $1.84/head in feed costs starting at weaning to raise it to a yearling. Plus, each year this calf is in the herd (feed savings of $6.40/head/year) and is mated with a superior feed efficient animal, you continue to realize feed savings over cattle not selected for RFI.

Calculate Expected Progeny Differences (EPDs)

Calculate an EPD for RFI using the heifers below. Throughout this module, the RFI values have been reported in kg or lb. on a dry matter (DM) or as fed basis. To ensure accurate calculations, use consistent units. DM is the preferred unit of measurement for RFI. Without knowing what diet the animal was tested on, we cannot convert the as fed to DM.

Heifer A
-RFI 0.483 kg As Fed
Adj Yearling wt. 811 lb.
ADG=0.98

Heifer B
+RFI 0.333 kg As Fed
Adj Yearling wt. 869 lb.
ADG 0.94

March 2011 born heifers from the Agriculture and Agri-Food Canada research station in Brandon , Manitoba.

Heifer B on the right will eat 204 kg more feed to reach the appropriate age and weight to be bred (at approximately 1100 lb.) than the efficient Heifer A on the left. For every 5 heifers like this in your herd, you will use an extra tonne of feed over the winter period.

1. Consider your breeding goals, desired traits and the list of bulls to choose from.

Potential Traits of Importance

a. Calving ease for heifers, low birth weight
b. Acceptable weaning wts and ribeye area for marketing calves
c. Structurally appealing (correct feet and legs, deep bodied, etc.)
d. Feed efficient
e. Acceptable milking ability in retained heifers

Your List of Important Traits

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

2. Select the bull you want to mate to the heifers based on traits of importance. Select those traits you wish to improve. For example, Heifer B mated to 11Z will result in progeny with +RFI, thus increasing feed costs. Mating Heifer A to either 92Z or 123Z will result in -RFI progeny; however, calving ease may be an issue if breeding 92Z to your heifers. The decision to mate the heifers to one of these bulls is not necessarily an easy one and will depend on the traits identified as important and marketing goals for their calves.

11Z

92Z

123Z

Bull ID	Calving Ease	Weaning Weight	Milk	Cow Weight	Stayability	Ribeye Area	Birth Weight	RFI, lb. As Fed
11Z	-0.1	46.3	12.8	77.1	0.9	13.2	88	+0.62
92Z	0.9	47.8	26.8	85.7	0.2	11.2	98	-0.45
123Z	-1.8	48.9	12.5	69.5	0.5	12.3	98	-0.71

Bull data and photos courtesy of Bar Pipe Hereford Ranch, Alberta

3. Calculate a simplified EPD for RFI using the following formula and the traits you selected.

(Bull RFI value x *Heritability) + (Heifer RFI value x *Heritability)/2 = estimated progeny RFI

Make sure to use consistent units to report RFI and note whether those values are positive or negative (kg or lb. of DM or as fed).

Example: +0.62 lb. As Fed divided by 2.2 = +0.282 kg as fed

*assumption with RFI is to use a heritability of 40 percent

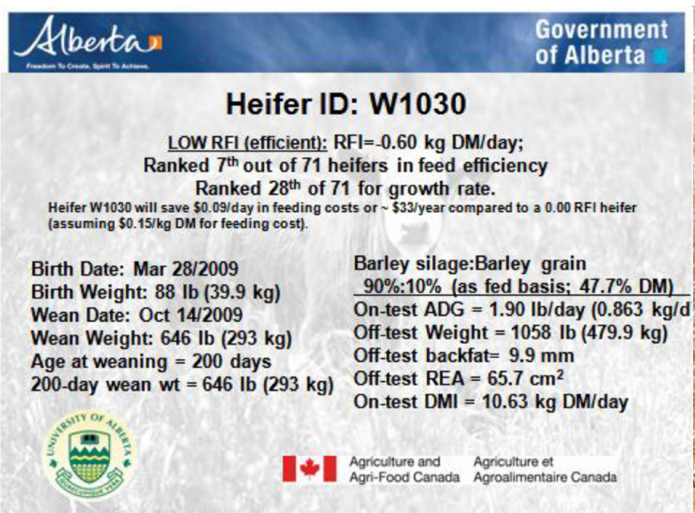
(________ x 0.4) + (________ x 0.4) = _________ divided by 2 = _________ progeny RFI

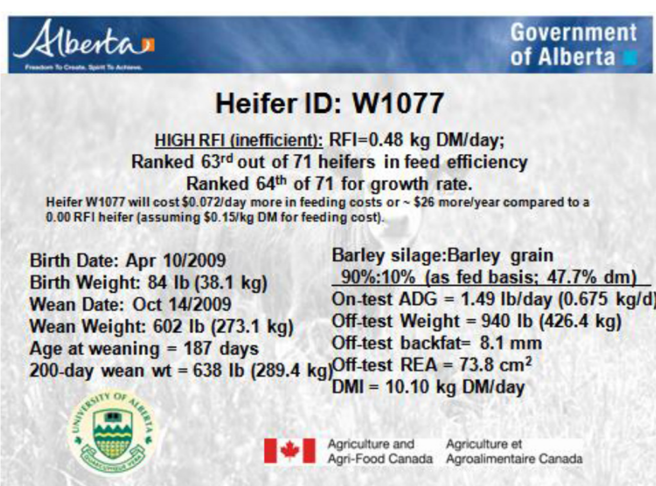
Considering Other Traits of Importance with RFI

The two commercial bred heifers below can be used to illustrate the selection of feed efficiency with other traits of importance. The data provided for each heifer includes age, test weights, gain (ADG), ribeye area (REA), backfat and dry matter intake (DMI). While the data supplied below was available prior to pasture turn out and breeding, it is more useful once the animals for potential retention in the herd have a confirmed pregnancy. You would cull those that do not breed and keep others based on their production data.

Example — Select From Two Bred Heifers

Compare the two heifers below. You should observe that they are similar in birth weight, weaning weights and backfat. Where they differ is in feed efficiency, ribeye area and average daily gain. You need to ask yourself, "If I select an animal based on improved feed efficiency, will I sacrifice other traits?" In this case, the efficient heifer is also superior for ADG but is inferior for REA. If you mate her to a feed efficient bull that is strong in her inferior trait (i.e., REA), you will still make genetic progress. However, if you mate her to a feed efficient bull also inferior for REA, you have sacrificed a carcass trait for feed efficiency.





Heifer data and photos courtesy of Agriculture and Agri-Food Canada Research Station, Lacombe, Alberta

Mature Cows - Considering RFI with Conformation

Heifer calves tested for RFI are likely to maintain their ranking of efficiency later into life. However, the diet they were tested on as yearlings may not be the diet they are maintained on as mature animals and this can affect RFI rankings.

What the Research Tells Us

Australian research determined that feed efficiency in yearling heifers has a 90 percent genetic correlation to mature cow efficiency. Research in Florida suggests that feed intake in yearling heifers is highly correlated to feed intake in the same females as lactating, four year old females (Leachman Cattle Company, 2012).

When you look at the cows below, you likely have a preference for one over the other based on appearance. When you find out they both weaned calves of similar weights and they both were pregnant, you are probably inclined to find the deep bodied, more feminine looking cow on the right more appealing.

RFI scores of the two cows tell a different story. The cow on the right ate 2.83 kg (6.2 lb.) more per day than the average cow in the herd and 5.4 kg (11.9 lb.) more per day than the other cow. Given this new information, you will likely reconsider your choice, given the impact on feed costs for a herd of 100s or 1000s of these feed inefficient cattle.

Cow data and photos courtesy of Agriculture and Agri-Food Canada Research Station and Dr. J. Basarab, Lacombe, Alberta.

LOW RFI cow efficient
(5 yr-old Hereford-Angus cow in the spring of 2004; RFI adj = -2.64 kg as fed/day; 2003 weight at weaning =787 kg).

HIGH RFI cow inefficient
(8 yr-old Hereford-Angus cow in the spring of 2004; RFI adj = +2.83 kg as fed/day; 2003 weight at weaning = 755 kg).

These are extremes in a herd and illustrate how conformation alone doesn't tell you the whole story on productivity and performance. These are large cows; however, the concept of feed efficiency is the same for other breeds and sizes of cows. The argument has been made by producers that their 1100 lb. mature cows are all efficient because they are smaller. Remember, RFI is independent of body size and weight, average daily gain and backfat thickness; variation and extremes exist in all populations.

Sourcing and Interpreting Numbers from Tested Cattle

In order to source breeding bulls that have RFI data, you need to contact your breed association or the association for the breed in which you are interested. Because facilities equipped with individual feed intake monitoring technology to rank cattle for RFI in Canada are limited, cattle with RFI data are also limited. However, more interest in selecting cattle for feed efficiency through RFI is creating a demand for more facilities that have the equipment to test.

Once you have found a reputable breeder who has RFI data on his bulls, you must be able to interpret the data in order to make the best use of it in your cow herd.

DOB June 2, 2006, RFI= -2.62 lb. as fed, ranked number 8 in his group of contemporaries.

EDPs from 2013 (in lb.)

EPDs	BW	WW	YW	Milk	REA	Marb
	1.8	62.4	111.4	26.9	0.35	-0.02
accuracy	0.64	0.52	0.41	0.21	0.35	0.34
%	60	3	3	30	90	50

Birth wt	Adj Weaning wt	Adj Yearling wt
95	620	1401

DOB May 31, 2009, RFI= -1.57, ranked number 1 in his group of contemporaries.

Bull Photos and data courtesy of Randy Bollum, R&R Acres, Airdrie, Alberta.

EPDs	BW	WW	YW	Milk	REA	Marb
	3.9	73.7	129.3	29.1	0.57	0.03
accuracy	0.56	0.47	0.22	0.22	0.22	0.22
%	100	1	1	10	50	30

Birth wt	Adj Weaning wt	Adj Yearling wt
104	711	1364

Steps to Select the Optimum Bull

Use the following steps to select an optimum bull for your breeding program.

1. Define your breeding goals.
2. List the superior and inferior traits of your cow herd.
3. Weigh the gains of certain traits with the losses of other traits in both your cow herd and the potential bulls.
4. Rank bulls for their superior traits that you require, including feed efficiency (RFI).
5. Assess the accuracy of the expected progeny difference (EPDs). Bulls with progeny will have higher accuracies compared to young or unproven bulls. For traits of importance to you, the higher accuracies will enable you to get more consistency in that trait.
6. Determine your preferred bull.

Evidence from Bull Test Stations

The following example from Montana helps summarize some of what you have learned about the value of selecting for negative RFI while, at the same time, avoiding single-trait selection.

Example

Selecting for Negative RFI and Other Desirable Traits

The McDonnell family, owners and founders of Midland Bull Test, east of Columbus, Montana in the US, have introduced the technology of GrowSafe Systems which is the same system Alberta research and industry testing have also been using to analyze the feed efficiency of individual live animals. RFI offers an improved alternative to traditional efficiency measures. It is a calculation of true feed utilization measuring differences in metabolic efficiencies. The concept of RFI is measuring the amount of feed an animal consumes above or below its maintenance requirements as well as its performance (growth) levels. “For example, let’s say we expect a given animal to consume 22 pounds of feed. But, we find through data collection this animal is only eating 18 pounds daily. This means the four pound reduction in intake is actually a negative RFI value,” says John Paterson, Extension Beef Specialist for Montana State University. “The concern is the research shows both of these animals had the same average daily gain (ADG). However, one animal is consuming 18 pounds of feed while the other is consuming 26 pounds daily to produce an equal amount of gain,” Paterson says. “It’s a no-brainer. Which animal do you want: the one that consumes more feed and has less gain, or the one that consumes less feed and has more gain?”

The potential long-term benefit of applying this GrowSafe technology is quite substantial. “Discovering we can save 60 dollars per cow annually, times the 1.6 million mother cows in the state of Montana is incredible. Now figure the average lifespan of a cow is around eight years, and we are talking about some pretty significant dollars,” says Patterson.

As important as RFI is, it represents only half of the performance testing equation. The second component is the animal’s ADG. Midland Bull Test, in conjunction with Montana State University, plans to use this information to continue to justify why the industry must continue to focus on a balance of multiple traits. “I think we get into trouble when we look at only a single trait, such as reduced feed intake. We want to use those EPDs for birth weight, weaning weight, feed yard performance and carcass characteristics together. Let’s use residual feed intakes and this residual feed conversion as one more tool for selecting cattle that are efficient but still have desired traits we want on the ranch—birth weight, weaning weight, yearling weight and carcass quality,” says McDonnell. “Whether you succeed or fail depends on how you utilize your resources. That’s why we’re putting so much emphasis on efficiency and residual feed intake. We need to be measuring traits crucial to the rancher’s profitability and get away from the hype and glitter that’s entered the industry in the last 10 years.”

See Module 3 Genetic Improvement for more information on EPDs.

Adapted from: http://www.midlandbulltest.com/efficiencytesting.php

Apply Feed Efficiency Technology in Your Herd - Feedlot Cattle

Photo courtesy of Spruceville Cattle Company, Alberta

Because improvements in RFI are related to improvements in feed conversion ratio (FCR), you can calculate feed savings that translate into improved profitability in the feedlot.

What the Research Tells Us

Research from Dr. John Basarab, Alberta Agriculture and Rural Development, has shown selection for -RFI cattle to improve FCR by 5 to 10 percent.

Keep in mind that when you select for -RFI, you must also select for superior growth (ADG) to see the benefits in feed to gain ratio. You need to select for the individuals that eat the least amount for the most amount of gain. Otherwise, you run the risk of selecting for animals that have a superior RFI with an inferior ADG. Remember, RFI and ADG are not correlated so there will be individuals that have the following:

- High gain and inferior RFI
- High gain and superior RFI
- Low gain and superior RFI
- Low gain and inferior RFI.

Example

Comparison of Most Efficient to Most Inefficient Calf

Using actual calf RFI values and 2014 feed prices with barley worth $165/tonne on a 77 day backgrounding ration with an ADG of 2.15 lb./day, the most inefficient calf in the pen (RFI= +2.8 lb./as fed) cost $29.58 more to get to 700 lb. than the most efficient calf (RFI= -3.6 lb./as fed).

What the Research Tells Us

While those are the extreme RFI values in a group of calves, the following example using actual data also yields impressive results in feed savings at $7.40/head over the 246 days or $11.35/hd/year.

Pen 1: 600 head on feed for 246 days, average RFI= -0.082 kg dry matter/day with average feed costs of $1.95/hd/d and feed:gain = 6.80 lb. or 3.10 kg

Pen 2: 600 head on feed for 246 days, average RFI= +0.068 kg dry matter/day with average feed costs of $1.98/hd/d and feed:gain = 7.13 lb. or 3.24 kg

With a 10 percent improvement in RFI, feed costs were reduced ($P < 0.05$) by $0.09/kg/day in an economic study of feedlot profitability with Angus and Simmental steers (Retallick et al. 2013). This translated to improved profitability of $11.47/steer.

(taken from J. Basarab, Alberta Beef Industry Conference, Red Deer, 2014).

Example: Profitability from Improving Feed to Gain Ratio Values

Calculate the improved profitability per head as a result of improving F:G values through selection of -RFI cattle with superior gain.

Assume a typical F:G of 7:1 (7 pounds of feed to get 1 pound of gain) in your feedlot to take 550 lb. calves to 1250 lb.

At 7:1 this equals 4900 lb. of feed required to take that calf to finishing weight.

A 5 percent improvement in F:G, as a result of selecting for feed efficient individuals through -RFI, would improve the F:G to 6.65:1.

At 6.65:1 this equals 4655 lb. of feed required to take that calf to finishing weight.

Using feed costs of $.07/lb., the feed savings or extra profitability associated with improved feed efficiency = $17.15/head.

What the Research Tells Us

The data below are taken from Leachman Cattle Company of Colorado who track progeny through to harvest to compare their performance with their expected progeny difference (EPD) predictions. Feed:gain EPD, calculated before collection of the data, accurately predicted the conversion seen in the progeny on a feedlot finishing ration.

The differences between sires of known RFI rankings added up to huge economic differences of over $164 per head when feed corn price was $6.00 per bushel.

Without knowing the RFI value of the sire, you might think the progeny were just larger, gaining better and converting better. However, because you know F:G is correlated to RFI, the improvement in F:G was due to the feed efficient (negative RFI) bull selection and the progeny which actually have lower feed intakes inherited from their sires.

Also, because RFI is not correlated to ADG, we cannot select for the highest gaining cattle to achieve an increase in feed efficiency. Some high gaining cattle eat a lot while other high gaining cattle eat less for that same gain and we need to know which cattle are which. The same is true of poor gaining cattle where some eat very little and some eat a lot for their low ADG.

See the Resource Section for more information on who to contact to get your herd's indexes developed.

Sire Group RFI (lb.)	# Head	Average Wt. lb.	ADG lb.	Dry Intake lb.	Actual F:G lb.	F:G EPD lb.	Feed Cost Difference
RFI +0.47	25	917	3.2	21.5	6.8	+.43	$90.65
RFI=0	28	915	3.5	19.7	5.7	-.01	($21.86)
RFI -0.39	32	926	3.4	18.3	5.4	-.32	($53.97)
RFI -0.58	48	937	3.6	18.9	5.2	-.54	($73.41)

Conclusion

You should now have the ability to apply feed efficiency and knowledge of RFI technology in your herd. This might be by making some decisions on which aspect of your herd is best suited to application of RFI. You should be able to calculate simple estimated breeding values for RFI and compare the potential feed savings from progeny of different matings. A clearer understanding of the relationship of RFI to feed:gain should now enable you to determine which breeding goals to pursue for your operation and which measurements of performance and profitability require closer documentation. Finally, you should understand that you will have other

traits beyond RFI that are important to you and thus need to make decisions based on multi-trait selection.

In the next module, you examine some of the additional benefits of RFI, including a reduction in manure production.

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8

Additional Benefits of RFI

After completing this module, you will be able to:

- **Describe the additional benefits of RFI, including reduced requirements for net energy of maintenance, reduced methane emissions and reduced manure production**
- **Identify types of records expected for access to Alberta's carbon market and other emerging environmental markets.**

Introduction

In the previous module, you learned how to apply feed efficiency technology in your own herd.

In this module, you start to examine some of the additional benefits of RFI, including reduced requirements for net energy of maintenance, reduced methane emissions and reduced manure production. These reductions result in savings for you, as a producer.

Reduced Carbon Footprint

In addition to the feed savings and the genetic improvement in feed:gain, cattle with superior RFI, after many (about 25) years of selection, will also have:

- Reduced requirements for net energy of maintenance by 10 percent
- Reduced methane emissions by 25 percent
- Reduced manure production by 15 percent.

All of the above reduce the carbon footprint of cattle compared to those not selected based on RFI.

One generation of selection for low RFI improves feed to gain ratio by 2.5 percent in feeders and replacement heifers and is worth $15 to $26/hd/yr in feed savings and about $1.50 to $2.00/cow in carbon credits.

What the Science Tells Us about Greenhouse Gases

Sixty to 75 percent of the greenhouse gas (GHG) emitted from various beef production systems comes from the cow primarily through CH_4 from enteric fermentation and N_2O from manure handling, storage and application (Beauchemin et al. 2010; Basarab et al. 2012). In the past, productivity improvements have occurred due to advances in nutrition, herd fertility, vaccines and animal health, genetic selection, pasture management, growth promotants and feed additives (e.g., β-adrenergic agonist), resulting in a 16 percent decrease in the carbon footprint per unit of beef (Capper 2011).

Despite these improvements in production, considerable reductions in GHG are still possible due to inherent inefficiency within beef production systems and the finding that maintenance requirements and feed efficiency of beef cattle have remained largely unchanged over the last 100 years (Archer et al. 1999; Johnson et al. 2003; Crews 2005).

In contrast, competing protein sources such as pork and poultry have made dramatic improvements in feed efficiency through both genetic and non-genetic means (Fairfull et al. 1998; Merks 2000; Chen et al. 2002; Hermesch 2004). Hume et al. (2011) recently reported that genetic improvements in layers, broilers, pigs and dairy have decreased CH_4 and N_2O emissions by 14 to 30 percent, while genetic improvement in beef and sheep have resulted in little to no reduction of CH_4 and N_2O emissions per unit of product.

Record Requirements to Create Carbon Offsets

Cattle release two types of greenhouse gas (GHG) emissions, methane and nitrous oxide, from digestion of feed materials in the rumen and from manure. Cattle that are more efficient in their feed utilization emit less GHG and can be produced through selective breeding using traditional EPDs or genomic ally enhanced EPDs for low residual feed intake (RFI). This management improvement can be linked to science-based GHG emission reductions, using carbon offset protocols approved by the Government of Alberta.

The following types of record requirements are expected to be needed to create carbon offsets in the Quantification Protocol for Selection for Low RFI in Beef Cattle.

In order to take advantage of carbon offsets, you need to keep records to establish a current feed efficiency baseline (3 year average of feed intake and ration data) and to document management improvements. If you select for low RFI cattle, you may qualify for carbon offsets in Alberta's unique carbon market, where regulated companies can buy offsets to meet their legal reduction requirements. While prices in the carbon market may be relatively low at this time, by keeping records, you may be able to access emerging environmental markets in the future. Changes to prices of carbon offsets in the future may make them very attractive.

Although not yet tested in on-farm conditions, the types of record requirements for the Quantification Protocol for Selection for Low RFI in Beef Cattle are listed in **Table 8.1 Overview of Expected Carbon Offset Record Requirements to Justify the Baseline and Project Condition**. On-farm tests will help to identify ways to streamline record keeping so record requirements may change with future versions of the protocol.

Additional details on the program are provided at: http://environment.gov.ab.ca/info/library/8562.pdf

Table 8.1 Overview of Expected Carbon Offset Record Requirements to Justify the Baseline and Project Condition

Record Requirements:	What is needed?	Why do you need it?
Animal identifier tag	CCIA, or similar Alberta Registry (Premises ID) tag	To track animals as they move through the various cattle rearing operations.
Documentation from a Certified Alberta or North American Residual Feed Intake (RFI) testing facility for cattle in the project	▪ Certified low residual feed intake-estimated breeding value documents for seedstock and progeny ▪ Accompanying documentation from the testing facility ▪ Farm records of matings	To confirm the RFI genetic merit technology to the appropriate cattle in the offset project.
Ability to demonstrate linkage of certified sire/dam to progeny and tracking of the animals in the project	▪ To ensure cattle in the project are RFI-certified according to the testing facility documentation, all sires in a breeding program would need to be RFI-certified OR ▪ The genetic linkage between sires/dam and progeny is proven through DNA testing ▪ The breeding program must be able to be defended and ensure proper tracking of relevant information.	To ensure the animals in the project have the estimated breeding values and dry matter intake values tested at the original facility, and computed by this protocol.
Characterization of the animal grouping methods in the baseline condition and project years Average number of animals per pen.	▪ Animal groupings in cow-calf, grazing and/or backgrounding operations are defined and signed off by a professional with relevant experience (e.g., DVM or P.Ag.); sample groupings are given in Table A2, Appendix D of the protocol). ▪ Documented feedlot records for the baseline and project condition consisting of: ○ approximate animal age as it enters the feedlot ○ animal pen entry and exit records that show average weights of the group in and out ○ date of entry (by production system, quality grid program, sex, breed, and/or custom feeding lot records (if applicable)) ▪ Average number of animals in each pen.	The methods used to define an animal grouping (i.e, sex, age, weight, breed, etc.) must be similar between project and baseline to ensure like groupings are compared for the offset calculation.

(table continued on next page)

Documented proof of what was being fed to the cattle per animal grouping/pen in the feedlot including the ration composition and days on feed for each ration for the baseline.	▪ Rations for cow-calf and backgrounding operations can be derived from available tools (see Section 1.3 of the protocol) ▪ Feed purchase receipts ▪ Delivery records for a pen ▪ Diet ration formulations signed off by a professional with relevant experience (e.g., DVM or P.Ag.), including any additive and edible oil content in the diet ▪ Proof from internal record keeping systems or third party files (such as Feedlot Health Management or ComputerAid or others). This must include: o the dry matter content o kilograms of feed delivered to each pen per day or as monthly totals o total digestible nutrients o crude protein content o number of days on rations o the level of concentrates in the ration.	To support calculations of the offset claim and third party verification. Note, a verifier will need evidence of the diets and total mixed rations fed to cattle groupings for the baseline and project condition.
Legal land location of the cow-calf, backgrounding and feedlot operation and any commercial agreements	▪ Legal land description for the registration of the project ▪ Land titles for the feedlot operation ▪ Any commercial agreements relating to ownership of the offset credits (see Section 5.5 of the protocol)	Registration of the project on the Alberta Emissions Offset Registry.

Reduced Manure Production

You can consider the reduced costs of manure hauling from your facilities to be a potential benefit of improved feed efficiency. The research has suggested that manure production from superior RFI cattle can be decreased by 15 percent compared to inferior RFI cattle. **Table 8.2 Custom Survey Rates for Corral Cleaning**, which has a range of costs for manure hauling from $85 to $600/hr, indicates that the reduction in manure production reduces your expenses.

Table 8.2 Custom Survey Rates for Corral Cleaning

Operation	Location	Most Common 2011	Range 2012	Most Common 2012
Corral cleaning	Alberta			
loader, 5 spreaders, 6 operators		$540/hr*	$560/hr*	$560/hr*
loader, 3 or 4 spreaders, 5 operators		$495-555/hr	$530-555/hr	$530-555/hr
loader, 3 spreaders, 4 operators		$380-450/hr	$380-450/hr	$380-450/hr
loader, 1 or 2 spreaders, 3 operators		$290-400/hr	$265-440/hr	$285-430/hr
loader only, 1 operator, for stockpiling		$95-150/hr	$85-140/hr	$95-140/hr
loader, 3 vertical beater spreaders, 4 operators		$470-565/hr	No Response to Survey	No Response to Survey
loader, 2 vertical beater spreaders, 3 operators		$510/hr	$520/hr	$520/hr
2 loaders, 5 spreaders, 7 operators		$775/hr	$775/hr	$775/hr
2 loaders, 4 spreaders, 6 operators		$650-670/hr	$650-670/hr	$650-670/hr
2 loaders, 2 operators		-	$180/hr	$180/hr
skid steer loader		$610/hr	No Response to Survey	No Response to Survey
truck mount spreader, 1 operator		$95-165/hr	$85-125/hr	$85-125/hr
truck mount spreader, vertical beater		$145-190/hr	$145-195/hr	$145-195/hr
dump truck mounted spreader		$230/hr	No Response to Survey	No Response to Survey
dump truck		$115-135/hr	No Response to Survey	No Response to Survey
excavator		$120-160/hr	$125/hr	$125/hr
excavator, 2-3 spreaders, 3-4 operators		$310-405/hr	No Response to Survey	No Response to Survey
skid steer excavator, 4 operators		$515-580/hr	No Response to Survey	No Response to Survey
skid steer		$85/hr	$85-100/hr	$85-100/hr
Total reports = 483 Surveyed Fall 2012				

Adapted from 2013 Custom Survey Rates Alberta http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf14268#corral

Conclusion

You should now have an understanding of some of the additional benefits of selecting for RFI cattle. Some of these benefits include reduced requirements for net energy of maintenance, reduced methane emissions and reduced manure production, all of which can help reduce your costs. You have also looked at the record keeping requirements that are needed to take advantage of carbon offsets and perhaps emerging markets.

The next module in this course examines some recent developments in feed efficiency and what you might expect in the future.

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9

The Future of Feed Efficiency

After completing this module, you will be able to:

- **Describe some developments in feed efficiency, including improved accuracies of estimated breeding values using genomic technology**
- **Connect infrared thermography to a potential reduction in time and expense to rank animals for RFI.**

Introduction

This module completes the discussion of RFI as a practical option for beef producers to reduce feed intake and lower costs of feeding. This final module suggests that the technology will continue to offer practical improvements for beef producers.

Feed efficiency will continue to be measured in cattle due to its economic value in beef production. However, researchers are currently exploring other technologies to use to enhance the phenotypic data that is collected from individual feed intake monitoring technology. These predictors of feed efficiency may one day be available for commercial use by beef producers.

Genomic Technology Research

Canada has a rich history in livestock genomics, with Canadian scientists playing prominent roles in the development of many important genomic-based innovations. These innovations will be able to increase efficiency, lower production costs, decrease the use of prophylactics, and limit the expenditure of resources. In no other sector of livestock production is the impact of Canadian scientists currently being felt more than the beef and pork industries. Two recently funded Genome Canada initiatives are leading the way in ensuring Canada maintains a leadership position globally in the cattle and swine industries. These are truly international collaborations of the scale required to accelerate progress in genomics research and application.

Genomic-based innovations can be used to:

- *Increase efficiency*
- *Lower production costs*
- *Decrease use of prophylactics*
- *Limit use of resources.*

Canadian Cattle Genome Project

Through funding from Genome Canada, one project, titled *"Whole Genome Selection through Genome Wide Imputation in Beef Cattle"* (also referred to as the Canadian Cattle Genome Project, www.canadacow.ca) is aiming to deliver genomic technology to Canada's beef breeders to enable them to substantially increase their rates of genetic improvement. At least 300 Canadian bulls will be sequenced, with this data forming an important part of the international 1000 bulls genome project (http://www.1000 bullgenomes.com/). Genotypes from a wide range of beef and dairy breeds will be used to develop accurate and robust genomic prediction equations that are applicable to Canada's cattle populations. Furthermore, low-cost genetic tests will be developed that will enable an animal's entire genome to be inferred (or imputed) from a relatively small number of strategically placed chromosomal markers, thereby providing valuable information as to its breeding value (Wang et al. 2012).

The Cattle Genome Project hopes to enable beef producers to increase their rates of genetic improvement.

Genomic technology may be used to improve the accuracies of estimated breeding values (EBVs).

Development of Molecular Breeding Values

The University of Alberta's Kinsella beef herd is being used to develop molecular breeding values (MBV) based on genome wide markers and/or high density marker panels for feed efficiency and cow-calf productivity to accelerate genetic and economic improvement.

The phenotype and genotype data generated for economically important traits like RFI and carcass will be useful for future research. The outcome of this research will be recommendations for you, as a beef producer, to adopt genomic technology in beef genetic improvement.

Relationship Between Genomics and RFI Project

To advance the potential in genomics, the Alberta Livestock and Meat Agency (ALMA) is partnering with Livestock Gentec and the University of Alberta on two projects on the relationship between genomics and residual feed intake (RFI). Scientists from Alberta Agriculture and Rural Development and Agriculture and Agri-Food Canada are also involved in the projects. Along with ALMA, Beef Cattle Research Council, Canadian Angus Association, Canadian Charolais Association and Beefbooster are also supporting these projects.

Development of EPDs for Beef Industry

A team lead by Dr. Plastow hopes to show the cost effectiveness of genomics.

Dr. Plastow leads a research team that is looking to create a program and tools that demonstrate how genomics and measures of efficient growth like RFI can increase cost effectiveness for cattle producers. The team has divided its test cattle into two herds (control and efficient), and will use genetic markers and other tools to keep improving the efficient herd and show the impact by direct comparison with the control. Over time, they will monitor all of the important traits in each herd. The cattle will then be finished in a feedlot and both groups will be compared to see the validity and effectiveness of the genomic tools.

Through this program, the team hopes to develop expected progeny differences (EPDs) for widespread beef industry use. Dr. Plastow believes that the demonstration of the effectiveness of the EPDs will help Livestock Gentec promote the economic benefits of genomic technology to producers.

As DNA marker panels grow in size, they will be able to track the inheritance of an increased number of genes associated with genetic variability in the trait of feed efficiency. What will be the benefit of higher accuracy values on young sires? For the seedstock producer, it will enable the selection of truly superior animals earlier in life. The benefit to commercial producers lies in the ability to buy yearling bulls with more certainty surrounding their EPDs.

Effect of Rumen Microbes on RFI

The project is also spurring further research on genomics. University of Alberta researcher, Dr. Leluo Guan, a recent winner of the Global Research Alliance Senior Scientist Award, is leading a team that is studying the possible effects that rumen microbes have on RFI in cattle. With recent studies suggesting a relationship between the two, Dr. Guan's team is looking into whether there is a genetic component to microbial function that could also serve as a marker for selecting efficient animals. Dr. Guan hopes that by identifying efficient animals and the microbes they carry in their rumens, producers can develop strategies that improve feed management.

Dr. Guan is researching the effects of rumen microbes on RFI.

"If microbial function can have an impact on RFI, then producers are given another way to select their cattle effectively," says Dr. Guan. "This allows their feed costs to decrease, while maintaining maximum feed efficiency for each animal."

Dr. Guan also sees another possible benefit in exploring the relationship between microbes in the rumen and RFI with genomics.

"Increased feed efficiency leads to less methane in the atmosphere; therefore, selecting animals with lower RFI could lead to reduced production of greenhouse gases that lead to global warming. That implies that increasing the use of genomics could lead to enhanced sustainability of the Canadian beef industry and provide a competitive advantage moving forward."

Genetic Evaluations for Feed Efficiency

(by Scott Bothwell, BIO)

Background

Individual feed intake can be recorded through feed intake systems such as the GrowSafe Systems Ltd. Key considerations for reporting genetic evaluations for feed efficiency are: good contemporary groups, feed delivery system maintained and working well, all animals allowed the same access to the feed troughs/hoppers where data is collected, good bunk management and manager/operator reviews daily feed logs to ensure all animals are able to access feed. Beef Improvement Ontario (BIO) produces across breed comparisons (ABCs) for traits of calving ease, birth weight, weaning gain, milk, yearling gain, scrotal circumference, hip height, ultrasound (backfat, ribeye, intramuscular) feed intake consumed and feed to gain. As part of reporting the genetic evaluation, we also report percentile rankings within breed and across breed. This allows for easy and accurate comparisons of bulls either within a breed or across breeds.

Defining Feed Efficiency

When interpreting the new feed efficiency evaluations, it is important to understand the biological point of reference which has been used. Animals are generally less efficient converting feed to gain during periods of slower weight gain, at heavier average weights, and during periods of fattening. Animals may also rank differently for feed efficiency during periods of lean growth, periods of fattening, or for maintenance at mature size. Average weights, gains, degrees of fattening and maturity are all variable among bulls in evaluation centres. Feed efficiency during the evaluation period must therefore be adjusted for differences in one or more of these factors.

The North American Beef Improvement Federation (BIF) recommends certain procedures be in place to adjust feed efficiency measures for the effect of differences in average body weight. BIO uses this recommendation in its evaluations.

Data That Needs to Be Captured

For feed to gain genetic evaluations, the usual necessary data for a typical genetic evaluation is needed: pedigree (including sire and dam), birth and weaning information; for BIO to calculate feed to gain and feed intake consumed, standard bull or heifer test type data needs to captured:

- Start of test weight and date
- A weight part way through
- An end of test weight and a backfat measurement and dates
- Dates for the start and end of the tracking period for feed consumed
- The cumulative amount of feed consumed.

Feed efficiency is typically calculated at the end-of-test as per typical bull testing guidelines. This is usually 112 days but can be as short as 70 days and as long as 168 days.

Best Use of a Feed Efficiency Evaluation

The best use of a set of genetic evaluations is to use them to simulate the use of a sire on a typical cow herd and report the differences in dollars made or lost by the "use of the sire". At BIO, these are called economic indexes. Adding a feed efficiency evaluation to the simulation model increases the accuracy. BIO currently uses feed efficiency evaluations in it BIO$ economic index. BIO also provides custom index calculations, using feed efficiency to various clients.

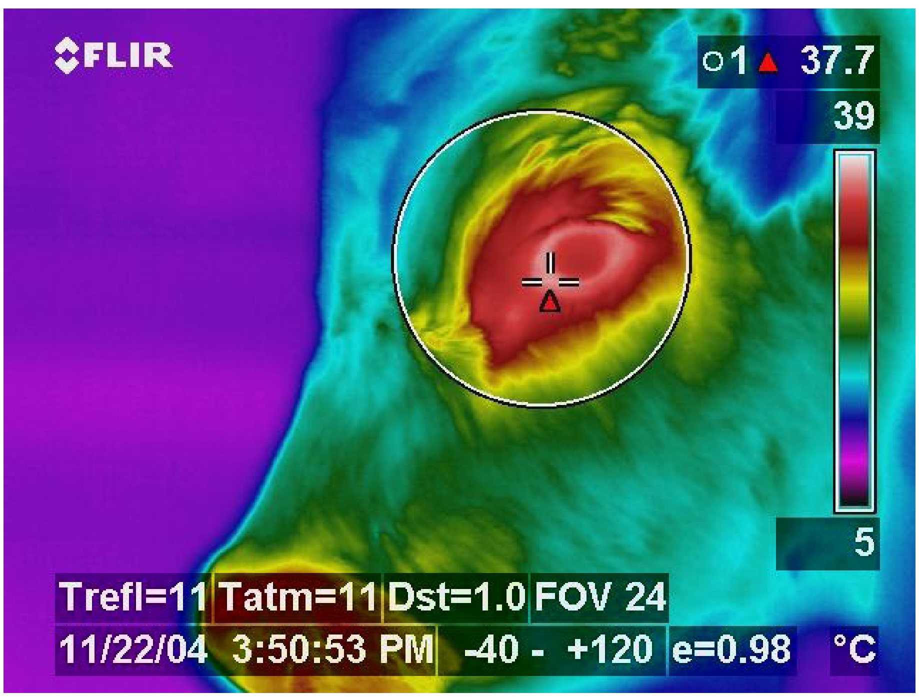
The Future

Continued research will involve the use of genomics to allow for more rapid data collection. This, is turn, can be used to build upon existing data sets for calculation of genetic evaluations.

Another area for research in feed efficiency and its application is for brood cows. How do feed efficiency evaluations, including genomics for feed efficiency, impact a cow-calf producer? Specifically, what does it mean for the carrying costs of cows?

Infrared Thermography (IRT)

Infrared thermography appears to have some use in screening yearling and mature cattle for low and high heat production (low vs. high RFI). This would reduce the time and expense to rank animals by individual feed intake for RFI by 80 to 90 percent. You can see how this might benefit your operation.



Example of infrared image of the orbital area of a calf. Computer color-enhanced profile shown.

You can remember it this way, "Being feed efficient is cool!"

What the Science Tells Us

Heifers with a negative RFI value (more efficient; n=30; mean = -0.598 kg d-1; SD= 0.445) displayed an infrared orbital average temperature of 25.64ºC (SE=0.315). In contrast, heifers with a positive RFI value (less efficient; n=31; mean=0.580 kg d-1; SD=0.559) displayed an orbital infrared average temperature of 26.62ºC (SE=0.336) (P=0.04).

In practical terms, heifers that display a negative RFI value would translate into a feeding cost savings of 430 kg per year. Data from this study suggest non-invasive measurements of IRT may be useful as a rapid screening tool to predict growth efficiency in heifers.

This data suggests that it is possible to rank metabolic efficiency within a two day period by using this non-invasive procedure at a cost of approximately $10/animal. However, this technology is still in the development and validation phase.

Conclusion

You should now have the knowledge to move forward with implementing RFI technology in your herd. Use the Resource Guide, as well at the modules, to help you make decisions on where you might start and who you might contact for more information.

References

ALMA Research and Development News. July 2014. Industry collaborates to help increase feed efficiency through genomics. http://alma.alberta.ca/News/index.htm?contentId=AGUCMINT-277606&useSecondary=true

Colyn, J.J., A.L. Schaefer, J.A. Basarab, E.K. Okine, T. Liu, K.L. Robertson, and S. Scott. 2008. Prediction of Residual Feed Intake in Beef Heifers by Infrared Thermography. Can. J. Anim. Sci. 89: 156.

Ludu, J.S., and G. S. Plastow. 2013. Livestock and the promise of genomics. www.nrcresearchpress.com.

Van Eenennaam, A. L. 2011. Improving EPD accuracy by combining EPD information with DNA test results. Proceedings of Applied Reproductive Strategies in Beef Cattle-Northwest. Boise, Idaho.

Wang, Y., Z. Cai, P. Stothard, S.S. Moore, R. Goebel, L. Wang, and G. Lin. 2012. Fast accurate missing SNP genotype local imputation. BMC Res. Notes, 5: 404. doi:10.1186/1756-0500-5-404.

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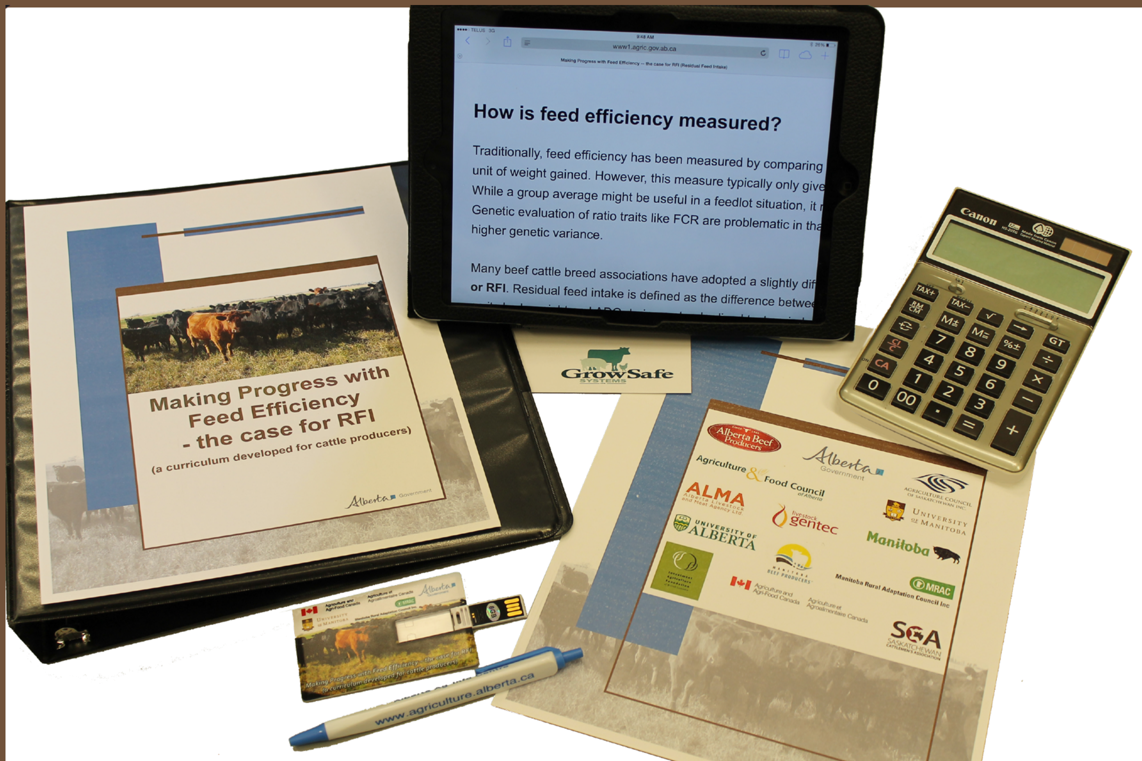
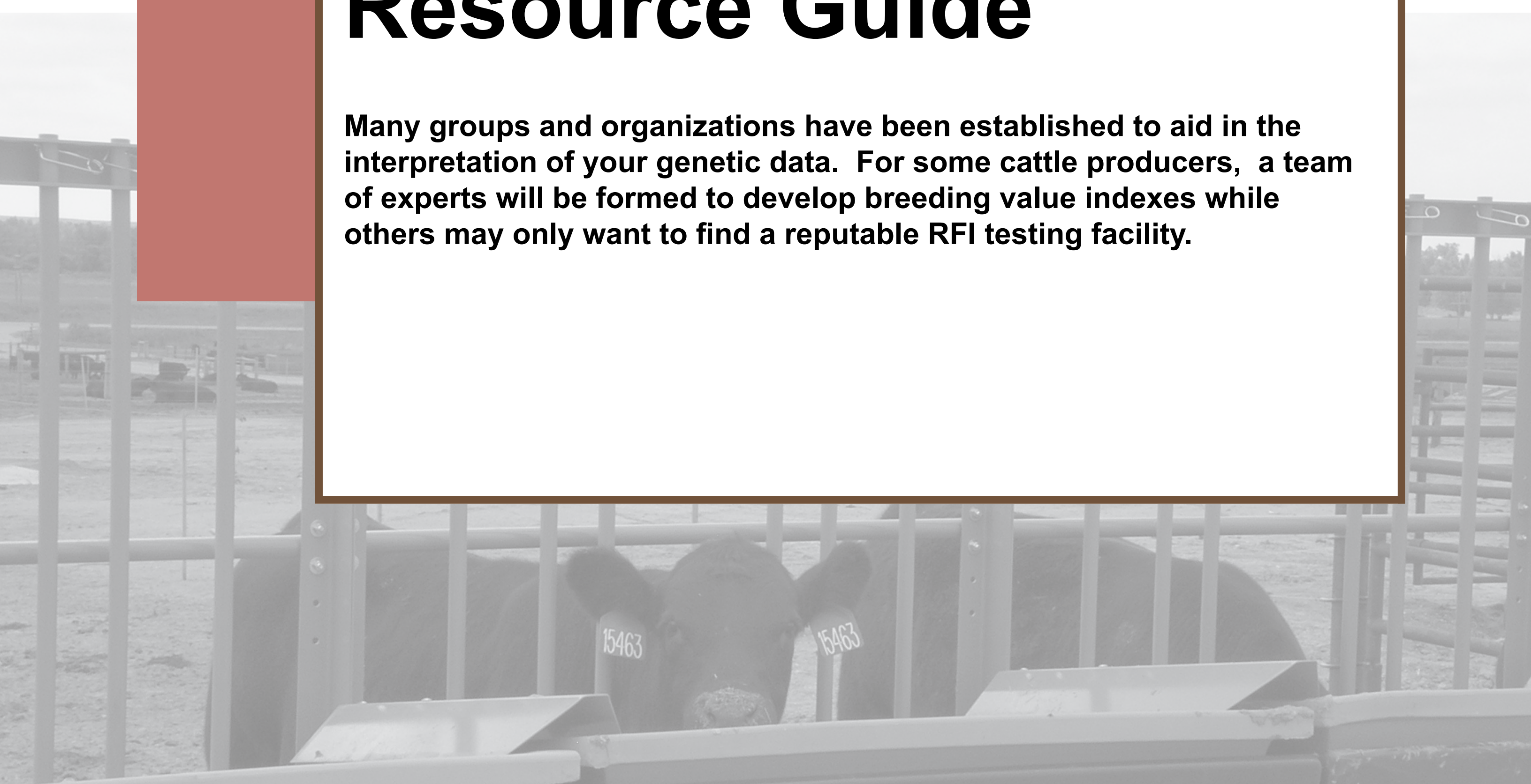
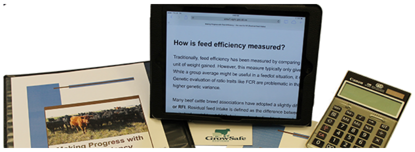
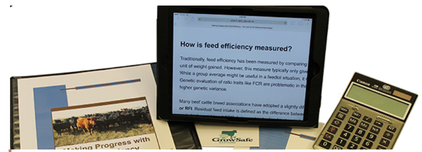


Resource Guide

Many groups and organizations have been established to aid in the interpretation of your genetic data. For some cattle producers, a team of experts will be formed to develop breeding value indexes while others may only want to find a reputable RFI testing facility.




How is feed efficiency measured?
GrowSafe



Groups

The following groups offer various services that may be of interest as you search for more feed efficient cattle.

Livestock Gentec

Livestock Gentec is an Alberta Innovates Centre, based at the University of Alberta. It was created to carry out and capitalize on world-class genomics research, bringing commercial benefits to the Canadian livestock industry.

Using advanced genomics tools can help livestock producers:

- Make selection decisions sooner by identifying top genetics earlier.
- Improve traits that are difficult to measure and therefore difficult to address with conventional breeding technologies.
- Improve return on investment through more efficient breeding and management.

For more information visit: www.livestockgentec.com

BIO

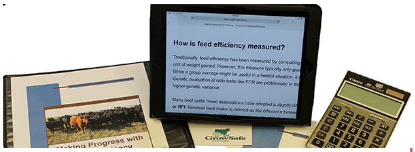
BIO is a Canadian based company with a mandate for genetic improvement. Their science is leading edge in a number of different areas. BIO has estimated across breed comparison EPDs on commercial and seedstock cattle in Canada since 1988. Economic simulation models have been used to generate indexes since 1996. BIO works in conjunction with the Centre for Genetic Improvement of Livestock (CGIL) at the University of Guelph in the development of new technologies for beef cattle improvement.

The technical team at BIO consists of experts, scientists and independent consultants who can calculate all of the underlying EPDs for interested cattle producers, beef breed associations and industry groups.

They designed the $Profit simulation model which includes a measure of feed efficiency and is in use by Leachman Cattle Company in the USA. Ensuring data integrity and model accuracy are key to the success of this program.

BIO’s team excels at generating the $Profit index exclusively for Leachman Cattle Company of Colorado.

For more information, visit:
www.biobeef.com and http://cgil.uoguelph.ca/



Beef Improvement Federation

The Beef Improvement Federation, based in the United States, was formed as a means to standardize programs and methodologies, and to create greater awareness, acceptance and use of performance concepts in beef production. Their mandate is to develop cooperation among all segments of the beef industry in the compilation and utilization of performance records to improve efficiency, profitability and sustainability of beef production.

For more information, visit: www.beefimprovement.org

Breed Plan Australia

Breed Plan Australia is a modern genetic evaluation system for beef cattle. Using best linear unbiased prediction (BLUP) technology, Breed Plan produces estimated breeding values (EBVs) for cattle for a range of important production traits including feed efficiency.

For more information, visit: http://breedplan.une.edu.au/

Canadian Beef Breeds Council

Canadian Beef Breeds Council (CBBC) helps individuals and organizations throughout Canada and around the world to access Canadian purebred beef cattle genetics and related services.

For more information, visit: www.canadianbeefbreeds.com

Breed Associations

Many breed associations are actively involved in research related to RFI. For further information, contact the specific breed in which you are interested.

Canadian Angus Association www.cdnangus.ca

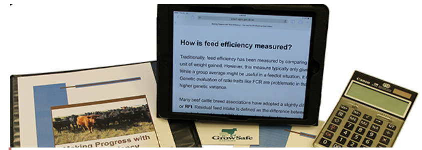
Beef Booster www.beefbooster.com

Canadian Charolais Association www.charolais.com

Canadian Hereford Association www.hereford.ca

Canadian Limousin Association www.limousin.com

Canadian Simmental Association www.simmental.com



Angus Genetics Inc. (AGI)

Established in 2007, Angus Genetics Inc. (AGI), a subsidiary of the American Angus Association®, was created to provide services to the beef industry that would assist in the genetic evaluation of traits of economic importance.

AGI develops and promotes technology for use by the beef industry, including DNA technology. AGI has developed genomic-enhanced EPDs for the Angus breed that are updated on a weekly basis. AGI also conducts research and develops and utilizes new science and technology to benefit all beef producers. AGI provides client specific genetic evaluation services to various breed organizations in the USA and Canada. www.angus.org

GrowSafe Systems

GrowSafe Systems had the first engineers to use RFID tags to monitor and assess production livestock. Today GrowSafe feed intake and behavior monitoring technology is used by more than 90 major agricultural research centers and premium seedstock centers worldwide to conduct livestock research and to measure feed efficiency.

See the attached appendix for more detailed information on GrowSafe or visit: www.growsafe.com

American Calan

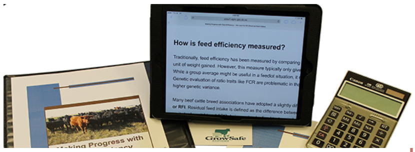
This specialized New Hampshire, USA based company designs and builds agricultural equipment used in the feeding and data collection of large animals at research facilities throughout the world.

For more information view their website at: http://americancalan.com/

Griffith Elder

Based in Suffolk, England, The Griffith Elder MealMaster™ Multi-Feeder System is an integrated system for precise control and monitoring of the complete diet intake of cattle.

For more information view their website at:
http://www.griffith-elder.com/ge_scales/cow-feeder



Insentec

Insentec BV from Marknesse, The Netherlands, offers The RIC (Roughage Intake Control) system enabling monitoring of individual feed intake and providing researchers at institutes and experimental farms with a wealth of valuable information.

For more information view their website at:
http://www.insentec.eu/en/cattle-mgt/ric-system

Igenity

See the end of this Module for information on interpreting DNA results.

Since its founding in 2003, Igenity has helped develop an extensive bioinformatics system to identify and predict an animal's positive or negative traits based on DNA test results. This information has helped livestock producers make significant improvements in genetics and improve overall quality.

For more information view their website at:
http://www.neogen.com/agrigenomics/Beef.html#Cattle

Zoetis

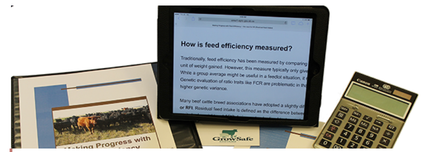
Their genomic testing procedure helps beef and dairy cattle or sheep producers make informed decisions and manage their livestock more effectively. By anticipating breeding results and identifying animals with the best genetic potential, they help producers optimize their profitability and yields. Zoetis offers the HD 50K (high-density DNA panel) for Angus.

For more information view their website at:
http://www.zoetis.com/products-services/genetics

Delta Genomics

They are a national, not-for-profit genomics service provider created as the service arm of Livestock Gentec. They provide biobanking, genotyping and sequencing services for members of both the livestock industry and livestock research community. They also provide contract research services for clients looking to conduct demonstration and validation studies to identify novel genetic traits in their animals.

For more information view their website at:
http://www.deltagenomics.com/services/beef-cattle/



Other Resources

A comprehensive scientific look at feed efficiency can be found in the book, “Feed Efficiency in the Beef Industry” edited by Rodney A. Hill, published 2012 by John Wiley & Sons, Inc. ISBN978-0-470-95952-7 (hardback).

A summary of this curriculum can be found in 3 fact sheets in Appendix 2 or at www.agric.gov.ab.ca

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/beef14856

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/beef14854

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/beef14858

YouTube videos on the topic of RFI can be found at:
http://www.youtube.com/watch?v=j7_SLo3EH94

Resources for Managing Livestock Manure, Source: Agdex 400/28-1. October 2008.

For more detailed information on manure management, consult the book Nutrient Management Planning Guide, 2007, available from Alberta Agriculture and Rural Development by calling 1-800-292-5697.

Greenhouse Gas Emissions and Mitigation for Beef - Selected Factsheets

General

Climate Change and Agriculture, at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl9706

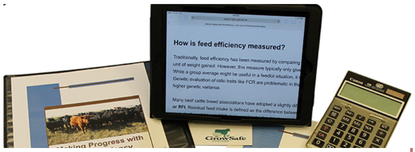
Greenhouse Gas Emissions and Alberta’s Livestock Industry, at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl9706/$File/GHGBulletinNo3Livestock.pdf

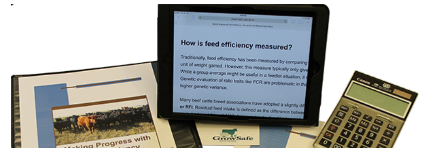
Specific to Carbon Offsets

Agriculture in the Alberta Carbon Market, at: www.agriculture.alberta.ca/agcarbonoffsets

Carbon Offsets for Agricultural Practices - Frequently Asked Questions, at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl14135

Capturing Benefits by Reducing Beef Emissions, at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl14131/$file/182-AlbertaOffset-Beef.pdf?OpenElement


How is feed efficiency measured?



THE IGENITY® PROFILE

Comprehensive. Practical. Powerful.

Using the power of DNA, Igenity provides cattle producers a comprehensive profile of individual animals. The easy-to-use profile includes analysis for economically important traits such as:

Carcass composition

- Tenderness
- Percent choice
- Yield grade
- Ribeye area
- Fat thickness
- Marbling

Maternal traits

- Heifer pregnancy rate
- Maternal calving ease
- Stayability

Feed efficiency

- Residual feed intake for Bos taurus
- Residual feed intake for Bos indicus

Docility

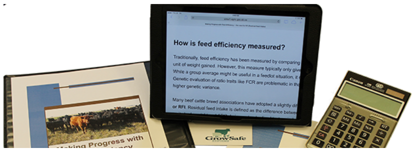
Average daily gain

Options

- BVD-PI
- Coat color
- Multi-sire parentage
- Myostatin – all variants
- Horned/polled
- Neuropathic Hydrocephalus (NH)
- Arthrogryposis Multiplex (AM)
- Contractural Arachnodactyly (CA)
- Osteopetrosis (OS)
- Tibial Hemimelia (TH)
- Pulmonary Hypoplasia with Anasarca (PHA)
- Coat Color Dilutor
- Idiopathic Epilepsy (IE)
- Hypotrichosis / Rat tail
- Chondrodysplasia (CHO)
- Dun Coat Color (DN)

Igenity® a Neogen® Company

geneseekinfo@neogen.com • www.neogenagrigenomics.com



INSIDE INFORMATION YOU CAN USE.

What an Igenity profile means. Igenity profile scores range from a low of 1 to a high of 10 for each economically important trait analyzed. This table shows the value associated with each score.

IGENITY PROFILE RESULTS AND ASSOCIATED EFFECTS*

Igenity result	Residual feed intake Indious**	Residual feed intake Taurus**	Average daily gain***	Tender-ness in lbs of WBSF	USDA marbling score	% Choice based on quality grade	Yield grade	Back fat thick-ness in inches	Ribeye are in square inches	Heifer pregnan-cy rate	Stayabil-ity	Maternal calving ease	Docility
10	5.5	4.2	0.81	-2.3	161.4	64.4	1.35	0.37	2.56	18.8	16.7	9.5	45.4
9	5.0	3.6	0.72	-2.0	141.3	57.2	1.21	0.32	2.22	16.2	14.7	8.4	39.6
8	4.2	3.1	0.64	-1.9	123.6	50.1	1.07	0.28	1.93	14.2	12.9	7.3	34.7
7	3.6	2.7	0.54	-1.5	106.4	42.9	0.92	0.24	1.64	12.1	11.2	6.2	30.0
6	3.0	2.2	0.44	-1.2	88.4	35.8	0.76	0.21	1.35	10.0	9.5	5.1	25.3
5	2.4	1.8	0.34	-1.1	70.6	28.6	0.61	0.17	1.07	8.1	7.6	4.1	20.5
4	1.9	1.3	0.24	-0.8	53.3	21.5	0.46	0.13	0.80	6.0	5.8	3.1	15.7
3	1.2	0.9	0.14	-0.4	65.5	14.3	0.31	0.09	0.53	4.0	3.9	2.0	10.7
2	0.6	0.4	0.05	-0.2	17.7	7.2	0.15	0.06	0.24	1.9	2.5	1.0	5.8
1	0	0	0	0	0	0	0	0	0	0	0	0	0
P-value	$5.7e^{-13}$	$8.04e^{-8}$	$2.4e^{-19}$	$1.9e^{-8}$	$3.8e^{-18}$	$1.0e^{-20}$	$1.6e^{-16}$	$3.9e^{-20}$	$1.8e^{-14}$	$2.6e^{-30}$	$1.1e^{-34}$	$4.2e^{-32}$	$3.1e^{-19}$

*Data on file at Neogen. Results expressed represent differences expected in animals compared to contemporaries with Igenity Profile scores of 1.

**Lbs of feed per day.

*** Lbs of gain per day.

How to read an Igenity profile. One of the greatest values of the Igenity profile is that all results are integrated and provided in one single profile similar to the report shown here.

IGENITY PROFILE

Animal ID	M/F	Breed	Sample barcode #	Homozygous black	Residual feed intake	Average daily gain	Tenderness	Marbling	% choice	Yeild grade	Fat thickness	Ribeye area	Heifer pregnancy	Stayability	Calving ease	Docility	BVD-PI	Polled
701	M	–	nv011507_01	Yes	8	9	8	8	8	8	8	9	9	8	8	7	POS	HP
702	F	–	nv011507_02	Yes	4	3	4	6	5	7	6	7	4	5	7	5	NEG	–
704	F	–	nv011507_04	No	6	7	3	8	6	6	3	4	8	6	3	6	POS	–
705	F	–	nv011507_05	No	5	3	4	6	5	5	6	4	5	6	5	8	NEG	–

Igenity® a Neogen® Company

NEOGEN AGRIGENOMICS
4665 Innovation Drive, Suite 120 • Lincoln, NE 68521
877/443-6489 • 402/435-0665 • Fax: 402/435-0664
geneseekinfo@neogen.com • www.neogenagrigenomics.com

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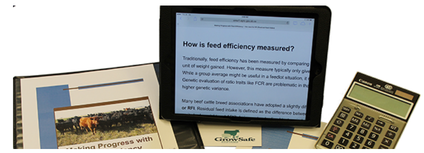
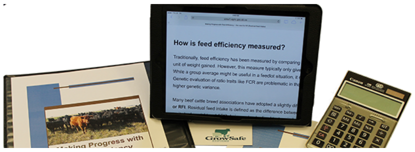
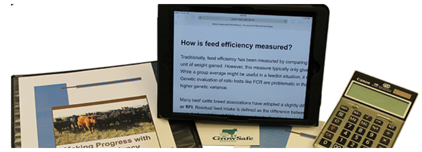


Appendixes


How is feed efficiency measured?
GrowSafe



Appendix 1 GrowSafe

Background

GrowSafe Systems Ltd.

GrowSafe Systems Ltd. (GrowSafe) develop automation tools and applications for livestock producers that maximize profitability through better decision-making, ensuring animal health and well being. GrowSafe feed intake and behavior monitoring technology has been installed in more than 90 major agricultural universities, research and seedstock centers worldwide.

GrowSafe Technology

GrowSafe's Model 6000® feed intake and behavior monitoring system is feedyard robust, reliable and can be operated simply by typical feedlot personnel in a commercial feeding environment. The system automatically measures individual animal intake and feed supply, undertakes bunk management and enables early sickness identification. A GrowSafe system is considered the gold standard for feed intake measurement in production environments worldwide. It offers unparalleled assurance of data accuracy with inherent data validation, diagnostics, audit trails and remote monitoring and technical support.

Beef Improvement Federation (BIF)

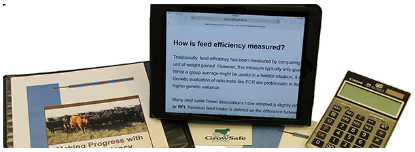
The Beef Improvement Federation (BIF) was formed as a means to standardize programs and methodology and to create greater awareness, acceptance and usage of beef cattle performance concepts, The primary purpose of the organization whose membership includes more than 40 state and national cattle associations is the establishment of accurate and uniform procedures for measuring, recording and assessing data concerning the performance of beef cattle. Information about BIF can be found on the Internet at http://www.beefimprovement.org/.

GrowSafe's program adheres at least to the BIF General Minimum Guidelines for Recording Individual Feed Intake in Growing Bulls and Steer and Heifer Progeny unless otherwise noted.

American Angus Association® (AAA)

The American Angus Association® (AAA) is the nation's largest beef registry association with over 30,000 adult and junior members. Its goal is to provide programs, services, technology and leadership to enhance the genetics of the Angus breed, broaden its influence within the beef industry, and expand the market for superior tasting, high-quality Angus beef worldwide.

GrowSafe's program adheres to the General Minimum Guidelines for Recording Individual Feed Intake in Growing Bulls, Steer and Heifer Progeny established by the AAA on September 5, 2008 unless otherwise noted. American Angus can be found on the Internet at http://www.angus.org/default.aspx



GrowSafe RFI Program

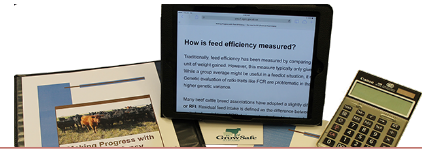
The intent of GrowSafe's program is to:

- Provide a detailed standardized RFI program to GrowSafe Stations measuring RFI.
- Ensure consistent collection of intake data between and across tests.
- Provide quality assurance of measurements.
- Provide the objective foundation for measured feed efficient market claims and assurance to purchasers that a GrowSafe certified sire is feed efficient and feed efficient progeny have been sired by a GrowSafe certified sire.
- Establish the process that will enable the development of automated "RFI calculation" software.
- Establish the data or table fields and process to enable secure exchange of data between a test center and breed associations or other allowed third parties.
- Establish the third party auditable basis for range conservation and carbon credits when they are available.

GrowSafe

GrowSafe Services Ltd. serves as a technology provider and a data management organization to support and develop a network of research facilities, ranches, feedlot and seedstock test stations (collectively known as Stations) that supply GrowSafe RFI measured feed efficient sires, semen from certified feed efficient sires, and progeny for sale to producers, ranches, auction barns, feedlots and other buyers.

Stations are trained and certified to use GrowSafe technology, input required mandatory data, exchange data with authorized users, and archive required data.



Operations Guidance - Monitoring and Measuring

Technology overview

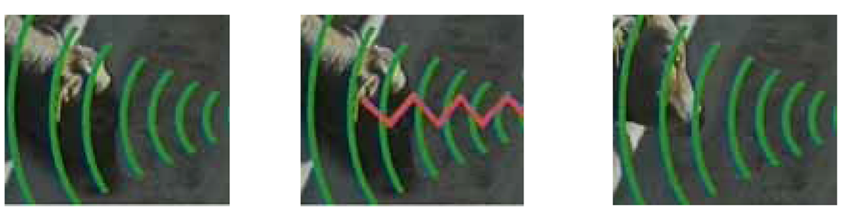
GrowSafe Feed Intake and Behavior Monitoring technology enables:

- Automated individual animal identification
- Comprehensive intake measurement
- Bunk management
- Feeding behavior monitoring
- Centralized data management – Open Data Base Connectivity (ODBC) compliant

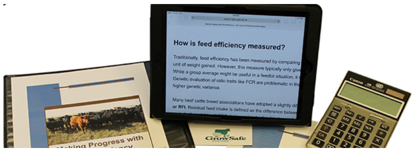
Data acquisition overview

1. Each animal is tagged with an ISO compliant HDX (Half Duplex) transponder mainly manufactured by Texas Instruments currently distributed in North America by Allflex. Each transponder provides a unique number which allows the animal to be individually identified. GrowSafe compliant HDX tags include:
    - 840 Series Button Tags distributed by Allflex (USDA/NAIS/CCIA/NLIS Approved)

2. A GrowSafe RFID antenna is molded directly in the feed trough which is suspended on two parallel load bars.
    - An electromagnetic field activates the transponder when the animal places its head in range of the antenna
    - The transponder emits a signal to the antenna identifying the animal
    - Each second the transponder is in range the GrowSafe data acquisition system records its presence at the trough (location and EID#) and the feed disappearance from the trough at a 10 gram resolution.
    - When the animal removes his head from the reading area, the signal stops



3. GrowSafe panels collects, verifies processes and stores data for transfer to GrowSafe analysis and management software installed on the station's dedicated data acquisition (DAQ) computer.



4. GrowSafe software gathers, segments, compiles, and analyzes the millions of data points collected by the system providing unique insight into animal health and performance. Everything required to acquire, analyze, present, store and enable data transfer is built in GrowSafe's data acquisition software package installed with every system.

GrowSafe data

GrowSafe collects the second by second data and each day processes intake records for each animal automatically in a database. GrowSafe Software is ODBC compliant, and can interact directly with any existing ODBC compliant database such as Oracle, Sequel Server, Microsoft Access, etc.

Main hardware components

The main hardware components of a GrowSafe Feed Intake and Behavior Monitoring System are:

- Master Panel (Base Station) - located next to DAQ computer
- Data Acquisition (DAQ) Panel - located close to feeding troughs
- Feed intake node metal frame
- RFID enabled feeding trough
- Data Acquisition (DAQ) Computer - standard PC running GrowSafe DAQ software.

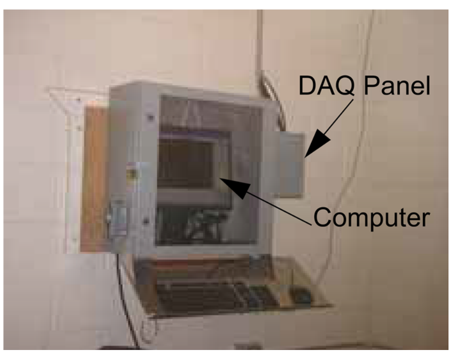


FIGURE 1. Master panel

The master panel is typically located beside the data acquisition (DAQ) computer and interfaces to the DAQ computer via USB or serial port. This panel continuously acquires data wireless from the DAQ panel.

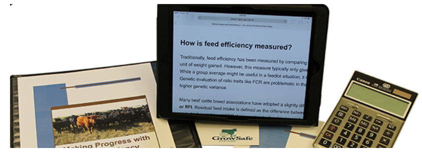


FIGURE 2. DAQ panel

The GrowSafe DAQ panel contains GrowSafe proprietary ID (tag 'reading') technology. The panel also contains the GrowSafe RF communication technology used to transfer data from the pen to the data acquisition computer. Data can be transmitted wireless up to 50 miles line of sight. The Growsafe DAQ panel contains auxiliary battery power allowing it to function for about 30 minutes during power interruptions.

Feed intake node

The GrowSafe feed intake node is the metal framing in which the trough is mounted.

FIGURE 3. Feed intake node

Each node is equipped with vertical headgate bars which, when installed, will allow only one animal to feed out of one trough at the same time. The bars can be adjusted to accommodate varying sized animals. A horizontal bar may also supplied.

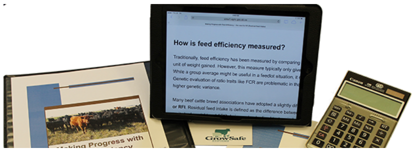
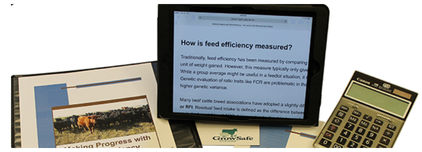


FIGURE 4. Feed intake node

FIGURE 5. RFID enabled trough

RFID enabled trough

The GrowSafe feed intake node comes complete with a heavy duty feeding trough made of FDA approved high-strength and high-impact resistant polyethylene. An RFID antenna to read the ear tags is molded directly in the feeding trough.



Trough capacity

Trough capacity is dependant on several factors such as:

- Type of ration being fed
- Amount of times the trough is filled per day
- Behavioral issues
- Average daily consumption of the animals
- Animal size.

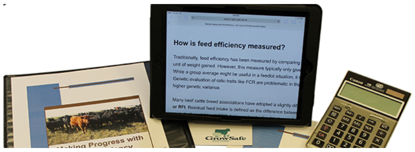
On test it is GrowSafe recommended not to exceed per node:

- 4 cows
- 8 bulls
- 10 steers
- 12 calves

(Note: BIF and AAA guidelines recommend 7 bulls per node)

GrowSafe 6000® Feed Trough	Capacity (Liters)	(kg)	Maximum Fill (kg)	(kg)
		Dry hay	Barley silage	Corn based ration
	532	84	190	338
GrowSafe 6000® Feed Trough	**Capacity (cu. ft.)**	**(lb.)**	**Maximum Fill (lb.)**	**(lb.)**
		Dry hay	Barley Silage	Corn based ration
	19	186	418	743

FIGURE 6. Trough capacity



Software

- A system will be installed with the most recent version of Data Acquisition Software. Currently this is ver10.58. All users that acquire GrowSafe extended warranty are upgraded to current versions.
- Everything required to acquire data and calculate individual animal intakes is included in the Data Acquisition Software.

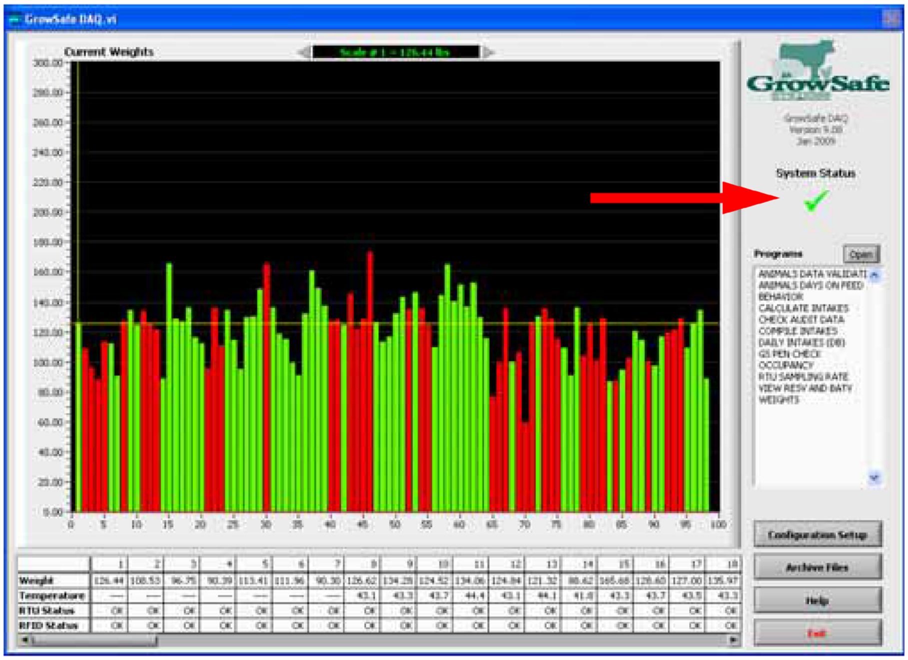


FIGURE 7. Main DAQ software screen

The main program screen of the data acquisition system will be seen by default at all times when the system is running and always displays real-time data collection.

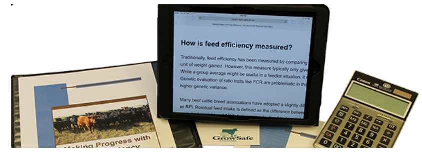
The real time status window displays the number of troughs connected to the system depicted as bars. The system displayed has 98 troughs.

- The weight in the trough is displayed on the Y scale. When there is no animal at the trough, the bars will be green.
- When bars are red this means an animal is visiting the trough.
- When the system is performing correctly, the status window will display OK across all troughs and the system status will display a green check mark.

Control of monitoring and measuring devices

GrowSafe technology is an advanced data acquisition system which offers sophisticated monitoring capability:

- Reads animal and non-animal activity at the bunk every second of the day.
- Reads an EID every second when an animal is consuming feed.
- Identifies when feed is consumed and a tag is not recorded.
- Records feed disappearance from the trough load cells every second of the day.
- Records substance appearance into the trough (feed, rain, snow)
- Access to sensitive data records are log-in controlled and password protected
- Check Audit Data software and system diagnostics automatically confirm whether data is valid.



General Test and Protocol Guidance

Warm up period

The current BIF minimum feed intake guidelines call for a conditioning (warmup) period of 21 to 28 days, with at least 14 days of this period in the testing facility.

If animals are acclimated on GrowSafe, the warm up period can be shortened to 10 days provided the following:

- Physical animal count = RFID animal count
- Animal intake is 'smooth' - all animals within established station tolerance levels
- All GrowSafe statistics are within tolerances.

Test period duration

Research has demonstrated that a minimum of a 70 day test period (following warm-up) is required to accurately record individual daily gain and feed intake. The test period should be defined as the final 70 day of a 80 day or longer test to ensure acclimation to the test conditions. During the test period, bulls should be consuming the final test diet ad libitum for all days.

According to BIF minimum guidelines, intake measurements obtained by GrowSafe, a minimum of 50 day of complete feed intake data is required.

Days where bulls are treated for sickness, removed from the pen for any reason (e.g., ultrasound, weights, etc.) should not be counted as a "test day". In sickness cases, full ad libitum intake should have resumed before data collection continues. Intake records should be the same or near to the same before the animal was removed from the pen.

Test period duration is greater as defined in the calculating RFI section.

Test diet

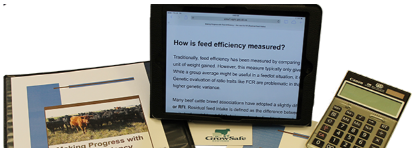
Appropriate performance test diets should be used during the test. All bulls or progeny within one test should be fed the same test diet, and the diet should be formulated to provide appropriate levels of energy to ensure expression of animal differences for intake. The ingredient composition of the diet should be recorded and should remain constant throughout the test period.

Random samples of the diet should be sent to a commercial laboratory for complete chemical analysis. All ingredient and chemical compositions of the diet will be done on a dry matter basis.

Age on test

Bulls entering a test facility must have birth date and weaning date recorded. From that and contemporary group definition, bulls within a feeding group should have a start of test age that is within a 90 day range.

Pen of feeding will also form a component of the test contemporary group. Individual feed intake data should be collected on bulls within the range of weaning age (e.g., 205 ± 45 d) to not more than 460 days of age.



GrowSafe software will automatically calculate age on test from DOB entry but it is the station's responsibility to determine that contemporary group requirements have been met.

Animal processing

- Cattle will be processed according to the station's standard arrival procedures.
- Each animal will be equipped with a GrowSafe compliant EID tag (transponder) which has been cross referenced in the DB to the Visual tag. This is an ISO compliant HDX (Half Duplex) transponder mainly manufactured by Texas Instruments currently distributed in North America by Allflex. Each transponder provides a unique number which allows the animal to be individually identified.
- Tagged animals are moved into GrowSafe equipped pens.

Live weight recording

Three methods of live weight recording conforming to the above are undertaken by GrowSafe Stations. When one protocol is selected, it must be followed throughout the test.

1. 2 consecutive day test weights taken test day 1 and final day with 1 midweight
2. For a 70-day test, biweekly (i.e., every 14 day) weights, whereas for a 112- day test, recording weights at 28-day intervals may be utilized
3. GrowSafe Beef continuous weighing - requires 1 chute weight on arrival and GrowSafe Beef daily weights recorded.

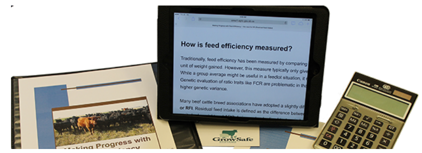
The first weight required by any of the above protocols will be taken on arrival when cattle are processed.

The GrowSafe Station is responsible for determining the weighing protocol and weighing timetable according to the chosen protocol.

Weigh dates and individual animal weights will be recorded in the GrowSafe database. GrowSafe will assist in direct data transfer from the chute scale files, export from spreadsheets or similar.

Animals moved into GrowSafe equipped pens

- Warm up commences when tagged animals are moved into GrowSafe equipped pens, or into specially designed warm up pens which are equipped with mock GrowSafe head gates.
- The system will automatically begin creating individual animal files when transponders are read. Individual animal file names are created by the system using the unique transponder number (EID#). Data reports include this unique number for every display, often linked to the visual tag.



Calculating RFI

Data required

Data required for residual feed intake (RFI) calculation are intake, average daily gain, backfat and average on-test metabolic body weight. All data will be recorded as or converted to kilograms. Intake data has been recorded daily and an average computed over the intake test period. Only days which have been marked as valid using the GS Pen Check routine will be used. The number of valid days can be viewed using the Animals Days on Feed routine.

The minimum numbers of on-test days that can be used to compute an average intake value are 85 percent of the days the animal was on the feed intake test (assumes at least 10 days of system acclimation). Intake data should be recorded as kilograms, or a conversion factor of 2.2 (0462262) lb. per kilogram should be used in converting intake data from lb. to kilograms. Intake data should be recorded as dry matter intake (determined at 55^{0}C).

Average daily gain and average body weight are both computed from body weight data of animals measured during the on-test period. Procedure for measuring body weight of animals must follow similar protocol throughout the test period. If animals are shrunk prior to weighing, the procedure for holding animals off feed should be followed at each weighing. If animals are weighed, full animals should be weighed prior to morning feeding on the day that body weights are measured. Procedure for weighing (shrunk vs full) should be noted in the database record. The initial weight of the intake test should be measured after calves have reached ad libitum (voluntary) intake. Ad libitum intake is established after 5 consecutive days where intake has not consistently increased daily. If weights are taken in pound units, conversion to kilograms should be made using the value of 2.2 (0462262) lbs per kg.

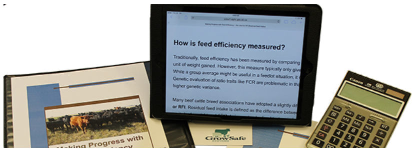
Average daily gain is computed as the change in body weight per day during the intake test period. Average daily gain can be computed by three methods, determined by the method that body weight was collected. Body weights can be measured on single days every two weeks (slope method), on two consecutive days at the beginning of the test period and on two consecutive days at the end of the test period (difference method) and daily by an in-pen weighing system (continuous method).

Slope method

A linear regression of body weight on day of test will be computed and the slope of this linear regression used as a measure of the animal's average daily gain. The correlation coefficient must be equal to or greater than 0.9 for the measurement of average daily gain to be considered accurate. The average on-test weight of the animal will be computed as the animal's initial weight plus the quantity of average daily gain multiplied by one-half the number of days the intake test was conducted. This method requires a minimum of 63 days on test.

Difference method

Average daily gain will be calculated as the difference in weight between the average of the ending body weights (average ending weight) taken the last two days on test and the average of the beginning body weights (average beginning weight) taken the first two days on test divided by the number of days the animals were on the intake test. The average on-test weight of the animal will be computed as the sum of the average ending weight and the average beginning weight divided by two. This method requires a minimum of 63 days on test.



Continuous method

Computing average daily gain and average body weight using this method requires that body weights be taken daily and an average body weight for each day be computed. To accomplish these measures, an in-pen weighing procedure is required. Average daily gain and average body weight would be calculated following the procedures outlined in the slope method. The primary difference is that daily monitoring of body weight allows accurate body weight change measurements to be made in a shorter time period than is possible when using chute weights. This method requires a minimum of 45 days on test.

Average metabolic body weight will be calculated as the average on-test body weight of the animal raised exponentially to the 0.75 power.

RFI is the residual difference between the actual intake of the animal and the animal's predicted intake based upon its body weight and average daily gain. To compute RFI, the expected intake (EFI) of the animal must be calculated. The EFI for each animal is based upon the animal's average daily gain and average metabolic body weight. The EFI predictive equation is generated by regressing intake on average daily gain and average metabolic body weight for all animals placed on the intake test. The regression equation yields coefficients for average daily gain and average metabolic body weight and an intercept that can be used to calculate predicted feed intake, or EFI. The EFI for each animal in the test is calculated by placing the animal's average daily gain and average metabolic body weight into the multiple regression equation and then solving for EFI. The correlation coefficient for the regression equation should be reported. RFI of each animal is calculated as the animal's actual intake minus the animal's EFI. The sum of the RFI for all animals on the intake test must sum to less than 0.0. Correlations of RFI to average daily gain, RFI to actual feed intake, and RFI to feed conversion ratio (feed consumed divided by average daily gain) should also be calculated and reported.

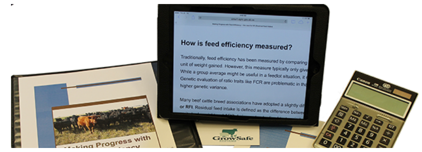
Ultrasound

Measurement of backfat by ultrasound in order to account for body composition when calculating RFI should also be used if collected. The ultrasound measures must be made by a certified technician. The backfat measurement would be incorporated into the multiple regression equation, with intake being regressed against average daily gain, average metabolic body weight and backfat. Backfat measures should be recorded in centimetre units. In calculating EFI, this component would be added to the intake prediction equation and each animal's backfat measurement used in the intake prediction equation. EFI and RFI would be computed as described above.

Ultrasound measures and technician used must be entered into the database to include this component in the final RFI measurement

RFI calculation software

Until RFI calculation software is completed, the calculation of RFI will be undertaken only by GrowSafe certified animal scientists, researchers, engineers and data technicians.



Technical Support and Training

Remote access by GrowSafe technicians

GrowSafe provides clients with remote service. Remote access is secured. GrowSafe engineers can remotely diagnose any system malfunction. They can also remotely access the DAQ computer to assist in data analysis, or training of research staff and technicians.

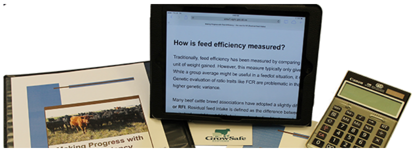
In May 2007 we transferred all clients to a web based service, to remotely service our customers over the Internet. GrowSafe pays for its access to this service to enable technical support; if a customer wants additional access privileges, this can be provided.

GrowSafe's remote server is configured to "watch" for certain events on the DAQ computer. GrowSafe has added a routine to DAQ Software, GrowSafe Watchdog which monitors our system for events we specify. Events include, but may not be limited to:

- Panel communication errors
- Database read write errors
- DAQ software started or terminated
- When DAQ computer is disconnected from the Internet. GrowSafe remote monitoring

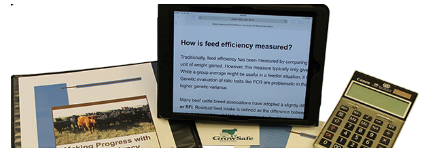
GrowSafe provides all new clients daily remote monitoring using Check Audit Data routine. This service is provided by GrowSafe at no charge through the 1st warranty year. This program ensures conformance to the requirements of the GrowSafe program and assists Stations in running compliant tests

Beyond the warranty period, stations can subscribe to GrowSafe remote monitoring service which includes daily remote monitoring and off-site server data backup.

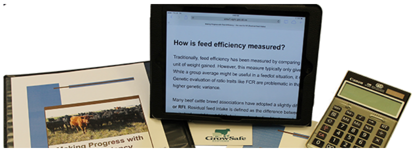


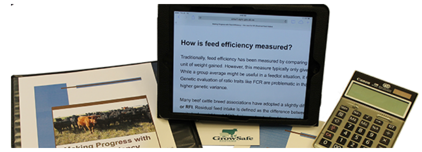
GrowSafe Systems Monitoring Technology

Site Name	State/Prov	Country
Adams Land and Cattle	NE	USA
Agri Research	TX	USA
Cattleland Feedyards	AB	Canada
Circle A Feeders	MO	USA
Clemson University	SC	USA
Colby Community College	KS	USA
Colorado State	CO	USA
Eagle Pass Ranch	SD	USA
Chinook Feeders	AB	Canada
Green Garden Angus	KS	USA
Green Springs Bulltest Station	MS	USA
Lacombe Research Center	AB	Canada
Lakeland College	AB	Canada
Lazy TV Ranch	SD	USA
Lethbridge Research Centre	AB	Canada
Lone Creek Cattle Company	NE	USA
Lucky 7 Angus	WY	USA
Midland Bull Test	MT	USA
Mississippi State Brown Loam	MS	USA
Mississippi State Prairie	MS	USA
Montana State	MT	USA
Montana State Pasture	MT	USA
Montana State-Havre	MT	USA
Namaka Farms	AB	Canada
Noble Foundation - Oswalt Ranches	OK	USA
Noble Red River	OK	USA
Olds College	AB	Canada
Olsen Ranches	NE	USA
Pet Kau Ent. Ltd.	MB	Canada
Powerline Genetics	NE	USA
ProfitMaker	NE	USA
Ridgefield Farms	NC	USA
Riverview Farms LLP	NE	USA
Sexing Technologies	TX	USA



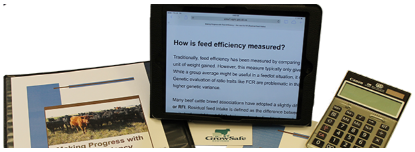
Simplot Land and Livestock	ID	USA
Snyder Livestock	NV	USA
Texas A&M BRU (College Station)	TX	USA
Texas A&M McGregor Research Center	TX	USA
U of Alberta - Kinsella Ranch	AB	Canada
U of Florida	FL	USA
University of Guelph - Elora Farms	ON	Canada
U of Idaho - Pasture	ID	USA
U of Idaho	ID	USA
U of Illinois	IL	USA
U of Illinois Dixon Springs	IL	USA
U of Manitoba - Dairy Unit	MB	Canada
U of Manitoba Beef Unit	MB	Canada
U of Missouri SW Farm	MO	USA
U of Missouri - Beef Farm Campus	MO	USA
U of Nebraska Lincoln	NE	USA
U of Saskatchewan	SK	Canada
USDA - Beltsville (Dairy)	MD	USA
USDA- Fort Keogh	MT	USA
Western Beef Development Center	SK	Canada
West Virginia University	WV	USA
West Virginia University - Dairy	WV	USA
West Virginia University - beef/dairy heifer	WV	USA
University of Wyoming	WY	USA
Wyoming Sheep	WY	USA
University of Wyoming - Extension Farm	WY	USA


How is feed efficiency measured?



Appendix 2 Fact Sheets from Alberta Agriculture and Rural Development

- Making Progress with Feed Efficiency
- The Economics of Feed Efficiency
- Frequently Asked Questions About Feed Efficiency and Residual Feed Intake



Making Progress with Feed Efficiency – the case for RFI (Residual Feed Intake)

Improving the feed efficiency of a herd can mean big savings for producers. Since feed costs represent greater than two thirds of total production costs in a beef operation, reducing them can have huge advantages to your bottom line. A 5 % improvement in feed efficiency could have an economic effect four times greater than a 5 % improvement in average daily gain (ADG). This means improving feed efficiency will have an effect on the unit cost of production and the value of the breeding stock and feeder animals.

How is feed efficiency measured?

Traditionally, feed efficiency has been measured by comparing the feed to gain ratio (Feed:Gain or FCR). Basically, this is the calculation of the feed consumed per unit of weight gained. However, this measure typically only gives you a group average and does not tell you what an individual animal was eating for the gain it got. While a group average might be useful in a feedlot situation, it really is of little value to a breeding herd where you want to make progress through genetic selection. Genetic evaluation of ratio traits like FCR are problematic in that selection response is unpredictable, usually placing higher than expected emphasis on the trait with higher genetic variance.

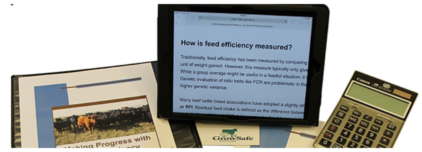
Many beef cattle breed associations have adopted a slightly different method of evaluating individual feed efficiency, called net feed efficiency, **residual feed intake, or RFI**. Residual feed intake is defined as the difference between an animal's actual feed consumed, or eaten, and the animal's calculated feed requirements based on its body weight and ADG during a standardized test period. Essentially, RFI describes the variation in feed intake that remains after the requirements for maintenance and growth have been met. Efficient animals eat less than expected and have a negative or low RFI, while inefficient animals eat more than expected and have a positive or high RFI.

Typically, RFI is measured in young cattle (7-10 months of age) in feedlot pens fitted with feeding stations designed to automatically monitor individual animal feed intake over a 70 day test (GrowSafe Systems Ltd., Airdrie, Alberta, Canada) following a three week adjustment to their test diet. Cattle are weighed before feeding on two consecutive days at the start and end of the test period and at approximately 14-28 day intervals. Because RFI is independent of mature size and body composition, they are also measured for ultrasound backfat thickness (mm), rib eye area (cm2) and marbling score at the start (optional) and end of the test period.

Individual feed intake is currently monitored with technology from GrowSafe® Systems of Airdrie, Alberta. This system collects phenotypic data to determine RFI.


Photo taken at the University of Alberta beef ranch, Kinsella, AB

Those animals that maintain themselves on the least amount of feed possible for acceptable performance will be the ones that save you in feed costs. The challenge is finding out who they are and selecting their genetics for the next generation so you continue to make genetic and economic progress.



Lessons learned

The pork and poultry industries have both taken advantage of genetics to select for feed efficiency. The pig's feed:gain improved from 3.8 lbs. per pound of gain back in 1972 to 2.6 lbs. in 2007. The broiler chicken also improved its feed:gain over that time period from 3.0 to 1.7 lbs.




Feed requirements moved from 836 lbs to produce a 220 lb market hog in 1972 to 715 lbs of feed in 2007 to produce a 275 lb market hog.

(adapted from David Casey, PIC Inc.; Graham Plastow, 2012)

For the beef cow, both the measures of DMI (dry matter intake) and ADG (average daily gain) are related to body size, growth and composition of gain. So, selection for improved F:G has resulted in cattle that grow faster (increased ADG), have increased mature size, and increased maintenance and feed requirements.

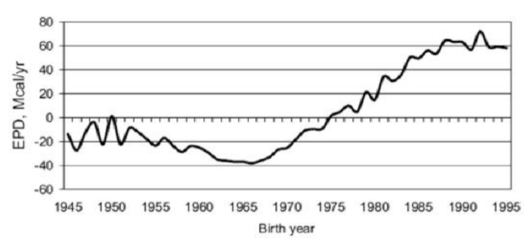
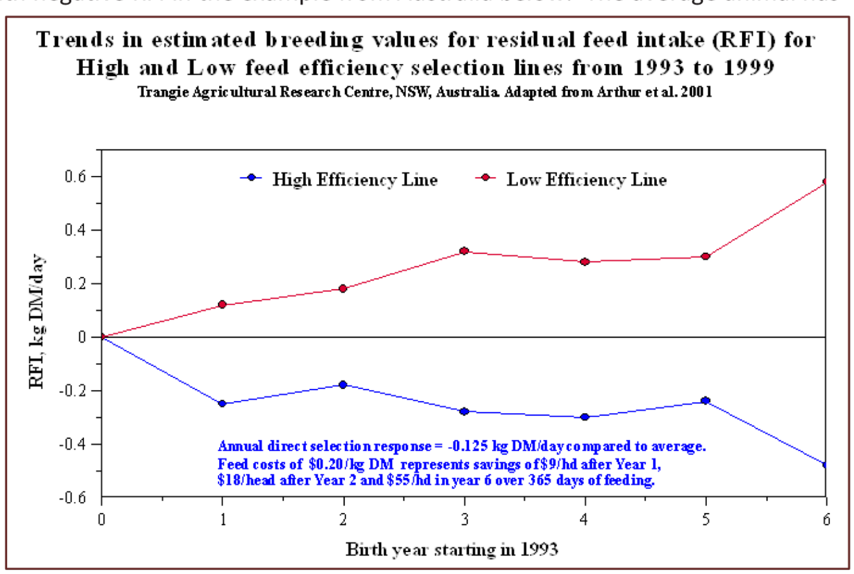


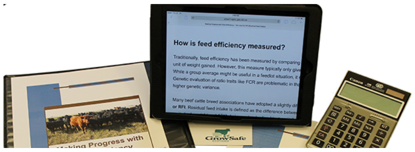
Figure 1. Average EPD (Mcal/yr) for mature cow maintenance energy requirements by birth year in Red Angus cattle (Evans et al., 2002).

The figure to the left shows 50 years of making bigger cows that ate more by selecting for the output of ADG. What has been forgotten to some extent is the selection for factors that could lower costs within the production cycle, like feed efficiency. Measuring and selecting for the *inputs* and not just the *outputs* needs some attention for the beef operation to continue generating income, but also to enhance sustainability and save costs.
What we don't want to do is select for growth only, at the expense of fertility and longevity. We need cows to stay in the herd and produce live calves.

Feed savings from -RFI cattle

RFI is considered to be a moderately heritable trait, suggesting substantial progress can be made if selecting for it. The feed efficient cattle are those with negative RFI in the example from Australia below. The average animal has an RFI of 0. Over 6 years, the savings in feed costs would amount to $55/head. Tremendous genetic and economic improvement is possible as long as you consider multiple traits like growth and fertility along with the feed efficiency trait.





Using RFI in a multi-trait selection breeding plan

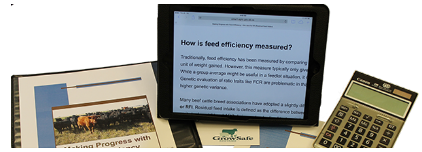
A summary of research on RFI by JA Basarab, Alberta Agriculture and Rural Development, (Tiffin Conference, January 2012) has shown that selection for low RFI (efficient cattle) will:

- Have no effect on growth, carcass yield & quality grade
- Reduce feed intake at equal weight and ADG by 10 to 12%
- Improve feed to gain ratio by 10-15%
- Reduce net energy of maintenance by 10% and reduce methane emissions by 25% and manure production by 15% (reducing the carbon footprint of cattle)
- Have little if any effect on age at puberty
- Have no effect on calving pattern in first calf heifers
- Have no negative effect on pregnancy, calving or weaning rate
- Have little effect on bull fertility
- Have a positive effect on body fatness or weight particularly during stressful periods
- Predict efficient mature cattle from younger growing animals.
- Will reduce feed costs: $0.07-0.10/hd/day feeders; $0.11-0.12/hd/day in cows

Photo of BeefBooster bulls taken at Thorlakson Feedyards Inc., Airdrie, Alberta

Finding negative RFI cattle

Currently, the easiest way to find feed efficient cattle (if you are not testing your own cattle) is to purchase feed efficient or negative RFI bulls to use on your cow herd. Genotyping, genomics technology and infra-red thermography are other methods being used to determine feed efficiency in cattle. Many bull test stations and large private feedlots, conducting research, have the technology to measure RFI for paying producers.



The Future of RFI

Data continues to be collected from collaborative research projects focused on feed efficiency and residual feed intake both in Alberta and internationally. Careful interpretation of the data when applying or adopting the technology to your beef operation is up to you to make the most of it. While there exists a large variation in the range of RFI values in animals, more than 35%, and because the trait is moderately heritable, significant genetic progress can be achieved in breeding programs resulting in cost saving benefits. For now, because we can't possibly test all cattle for RFI, contact your breed association to get a list of RFI tested sires for sale at upcoming bull sales. Introducing sires with a known RFI value is a first step to moving your cow herd toward increased feed efficiency since 80-90 per cent of the genetic improvement in a herd comes through the sires. However, with time and continued improvement in genomics and infra-red thermography technologies, the ability to detect efficient animals will improve and increase our ability to select superior animals.

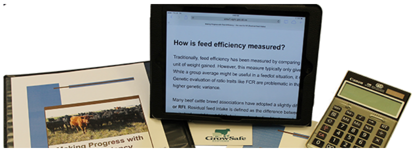
References

Arthur, P.F., G. Renand and D. Krauss. 2001. Genetic and phenotypic relationships among different measures of growth and feed efficiency in young Charolais bulls. Livestock Prod. Sci. 68:131-139.

Evans, J.L., B. L. Golden, and B. L. Hough. 2002. A new genetic prediction for cow maintenance energy requirements. http://www.bifconference.com/bif2002/BIFsymposium_pdfs/Evans_02BIF.pdf.

This is the first in a series of fact sheets on RFI. The other titles are: "The Economics of RFI" and "Frequently Asked Questions about RFI".

For further information on feed efficiency go to www.agriculture.alberta.ca to search for RFI, Residual Feed Intake or Net Feed Efficiency for cattle producers. Additional information can be found at www.livestockgentec.com and www.growsafe.com



The Economics of Feed Efficiency – the case for RFI

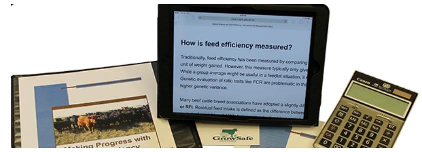
Feed costs represent up to 70% of the production costs in a beef operation and it only makes sense that feed efficient cattle should be more profitable. Residual Feed Intake, or **RFI** is a trait that explains the difference between what an animal is expected to eat and what it actually eats for a given body weight, growth rate and body composition. Because RFI is moderately heritable (35-40%), we can make genetic progress by selecting for cattle with negative RFI who also have desirable growth, carcass merit, fertility and lifetime productivity. This allows us to get paid for the outputs of calf or yearling weight and/or meat yield, yet allowing us to save on feed costs, especially for our females back at the ranch. It's a win-win! We'll produce efficient, productive cattle on fewer feed related resources plus those cattle with negative residual feed intake (-RFI) are known to produce less manure and have lower methane emissions making them more environmentally sustainable, a definite benefit for our social license.

Profit drivers for the cow ranch and the feedlot are closely related. For the cow herd, how much she eats, early season breeding, her calf weaning weight and stay ability are very important. The top factors affecting profitability of feedlot calves are related to feed to gain ratio (43%), market or grid value (39%), carcass weight (18%) and animal health (1%), so you should be just as concerned over feed efficiency as you are with the market price.

The Feed Efficient Sire

In animal breeding, response to selection is based on intensity of selection (i), accuracy of selection (r), genetic standard deviation (SD) and generation interval (L) or genetic change = (i x r x SD)/L. The annual rate of genetic response, when we consider the entire herd over many generations, is over-estimated, since cattle breeders will select for multiple traits or use multi-trait selection indices. Keeping this in mind, let's look at some simplified examples:

Bull A 92Z				**Bull B 14Z**			
RFI -1.45 lbs DM/day				**RFI +1.11 lbs. DM/day**			
EPDs	**CE**	**WW**	**Milk**	**EPDs**	**CE**	**WW**	**Milk**
	+0.9	**+47.8**	**+26.8**		**+1.5**	**+48.9**	**+17.4**



Compared to an average bull with RFI=0, Bull A will sire calves that eat less while Bull B will sire calves that eat more for their performance when mated to the average (not selected for RFI) group of cows. With simplified calculations for an estimated breeding value (EBV), you may expect:

Bull A; with an RFI= -1.45 lbs DM/day x 0.63x0.63= -0.58 lbs DM/day

If mated to RFI average cows of his same breed, cow RFI EBV=0
Progeny are expected to perform at (-0.58 + 0)/2 = -0.29 lbs DM/head/day

These calves will, on average, eat 0.30 lbs less feed on a dry matter basis each day. On a typical 2014 priced forage based backgrounding ration for 115 days, costing $0.065/lb/day or $0.14/kg/day DM basis, this set of calves saves you $2.24/head in feed. Replacement heifers retained from this sire save you the $2.24/head during the backgrounding phase, plus an additional $7.12/head/year in feed meaning these heifers were $9.36/head cheaper to raise to first calving in feed costs alone compared to an animal with EBV for RFI=0.

Bull B; with an RFI= +1.11 lbs DM/day will sire progeny with an expected RFI **=+**0.22 lbs DM/day if mated to RFI average cows of his same breed with EBVs for RFI=0. These calves will cost you $1.64/head in feed for the backgrounding phase and will cost you an additional $5.22/head/year to raise to first calving meaning these heifers were $6.86/head more expensive to feed than an RFI=0 animal.

Compared to Bull A, the replacement heifers of Bull B cost you $16.22/head more to feed from weaning to first calving.

The Feed Efficient Replacement Heifer or Bull Calf

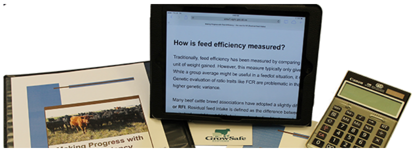
As a breeder, if you have selected for feed efficient females, like a daughter from Bull A, and you mate her to a –RFI bull, more genetic progress in feed efficiency will be made resulting in additional savings in feed costs. Remember, this is not about single trait selection for feed efficiency, rather, you need to consider RFI as an additional trait with your typical breeding goals.

Bull C RFI= -1.06 x 0.4 heritability = -0.42 lbs DM/day

Replacement Heifer (purebred daughter of Bull A) RFI= -0.29 x 0.4 heritability = -0.12 lbs DM/day

Progeny expected (average of the parents) -0.42 + -0.12 = -0.54/2 = RFI -0.27 lbs DM/day

This calf will save you $1.84/head in feed costs starting at weaning to raise it to a yearling. Plus, each year they are in the herd (feed savings of $6.40/head/year) and are mated with superior feed efficient animals you continue to realize feed savings over cattle not selected for RFI.



The Feed Efficient Feeder Calf

Being able to source cattle with improved Feed:Gain as a result of selection for -RFI parents will yield significant feed savings in the feedlot or backgrounding lot. Because RFI is not correlated to growth,(ie ADG) you will not have to give up gain for the reduced feed intake.

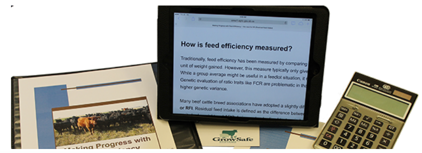
Using actual calf RFI values and 2014 feed prices with barley worth $165/tonne on a 77 day backgrounding ration with an ADG of 2.15 lbs/day the most inefficient calf in the pen (RFI= +2.8) cost $29.58 more to get to 700 lbs than the most efficient calf (RFI= -3.6). While those are the extreme RFI values in a group of calves, the following example using actual data also yields impressive results in feed savings at $7.40/head over the 246 days or $11.35/hd/year (taken from J. Basarab, Alberta Beef Industry Conference, Red Deer, 2014).

Pen 1. 600 head on feed for 246 days average RFI= -0.082 kg dry matter/day with average feed costs of $1.95/hd/d and Feed:Gain = 6.80 lbs or 3.10 kg

Pen 2. 600 head on feed for 246 days average RFI= +0.068 kg dry matter/day with average feed costs of $1.98/hd/d and Feed:Gain = 7.13 lbs or 3.24 kg

The Feed Efficient Cow Herd

Feed cost savings will be realized after years of purchasing –RFI bulls and retaining superior RFI heifers for breeding. Additional benefits from improved RFI cattle that speak to your social license and environmental sustainability include: reduced methane emissions of 20-30% and reduced manure production of 10-20%, in addition to improved Feed:Gain by 10-15%.



1.Cow on left RFI= -2.64 kg as fed/day

2. Cow on the right RFI= +2.83 kg as fed/day

These 730 kg (1600 lb) cows are expected to eat about 2.2% of their body weight on a dry matter basis. Their feed consumption on a typical forage based ration would amount to 18.8 kg (41.4 lbs) as fed.

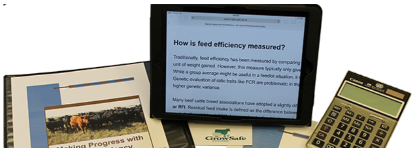
1. If you selected for the –RFI cow and her progeny and have other females like her in your herd, plus purchased –RFI bulls to breed her and her progeny to, you would have realized;
   Estimated breeding values in a simplified way to determine the genetic effect of the parents
   Cow RFI= -2.64 kg x heritability of 40% = -1.06 kg/d
   Bull RFI= -1 x heritability of 40% =- 0.4 kg/d; therefore the progeny are expected to perform at (-1.06 + -0.40)/2 thus EPD RFI=- 0.73 kg/d

2. If you selected for the +RFI cow and her progeny and have other females like her in your herd and you did not search out –RFI bulls, thus RFI=0 on your bulls.
   Estimated breeding values in a simplified way to determine the genetic effect of the parents
   Cow RFI= 2.83 kg x heritability of 40% = 1.13 kg/d
   Bull RFI=0 x heritability of 40% = 0; therefore the progeny are expected to perform at RFI= +0.57 kg/d

-0.73 + 0.57 = 1.3 kg/head/day less feed for the -RFI selected herd in 2014 feed prices with forage based cow rations priced at $0.12/kg multiplied by 365 days = $56.94/cow/year.

The feed differences in the two scenarios would mean a significant feed savings of close to $60/cow/year. Put another way, this 5 to 10% improvement in feed efficiency translates into having your current land and feed resources but being able to run 5 to 10 more cows for every 100 cows you now have.

The above actual real Alberta examples show that finding a breeder who has RFI tested cattle has economic benefits. After setting your typical breeding goals for your cow herd plus looking at bull conformation, semen test, EPD's and expected purchase price in addition to RFI, you can make improvements on the ranch that include reduced feed costs and improved feed:gain in the progeny regardless of being backgrounded, put on pasture, retained as replacement heifers or put in a finishing lot.



The Value of the RFI bull test

If you breed purebred cattle and want to measure feed efficiency in your superior conformation and performance bull calves, a standard bull test for 20 head costs about $7000.00 or $350/head at the Cattleland National Bull Evaluation Centre, in Alberta (based on 2011 costs from Cattleland Feedyards Ltd).

The bull test for RFI requires at least 70 days on the GrowSafe individual feed intake monitoring system in addition to approximately 3 weeks on a start up ration. Costs are estimated at 2011 values to be $590/head based on a 20 head minimum. The difference of an RFI test over the standard bull test is about $150 - $250 depending on services provided during the test.

Through an RFI test, not only have you identified the superior genetics of the feed efficient bulls to build more efficient cow herds, but –RFI bulls are likely to sell for a higher value compared to the feed inefficient bulls. The Midland Bull Test Station in Columbus, Montana, which can test over 1200 bulls per year, collected data from their annual sales of RFI tested bulls over many years and found –RFI bulls brought up to $300 per head more than bulls with +RFI scores.

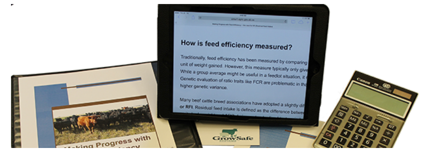
Sourcing RFI tested cattle for genetic improvement in your herd and culling the bottom 25 to 30% of your inefficient cattle will take you a long way to saving feed costs, increasing live animal value and building a more sustainable cattle population.

This is the second in a series of fact sheets written by Dr. Susan Markus, the other titles are:

"Making Progress with RFI" and "Frequently asked Questions about RFI"

For further information on feed efficiency go to Alberta Agriculture and Rural Development's home page www.agriculture.alberta.ca to search for RFI curriculum for cattle producers. Additional information can be found at www.livestockgentec.com and www.growsafe.com

Alberta Government
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Manitoba
ALMA Alberta Livestock and Meat Agency Ltd.
University of Alberta
University of Manitoba
livestock gentec
Manitoba Beef Producers
SCA Saskatchewan Cattlemen's Association
Alberta Beef
Agriculture Council of Saskatchewan Inc.
Investment Agriculture Foundation of British Columbia
MRAC Manitoba Rural Adaptation Council Inc.
Agriculture & Food Council of Alberta



Frequently Asked Questions about Feed Efficiency and Residual Feed Intake (RFI)

Q. Why can't I just use the feed conversion ratio, Feed:Gain, as a measure of my cattle's feed efficiency? If I can improve the number, surely I am selecting for feed efficient cattle.

A. On any farm it would be difficult to accurately measure the feed intake of an individual animal because most do not have the time, equipment or resources to measure it. When measuring a group of cattle – whether calves, cows or bulls, the Feed:Gain will be giving you an average for the group and you will not know which animal ate the least and which one ate the most. Within a population of animals of the same class (similar age, breed, weight and management), the spread or variation in feed intake of two animals gaining at the same rate can be 35% or more. If you selected based on Feed:Gain you would essentially be selecting for growth rate (ADG) and mature size. The beef industry has already done this and over the last 25 years we have increased mature size of our cattle and we know these cattle eat more but are not necessarily producing or performing better.

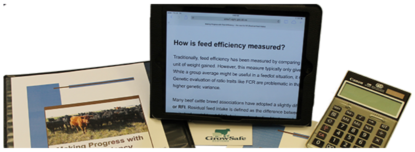
Traditionally, feed efficiency in beef cattle was defined as feed to gain ratio or feed conversion ratio (**FCR**). However, genetic evaluation of ratio traits like FCR are problematic in that selection response is unpredictable, usually placing higher than expected emphasis on the trait with higher genetic variance. Further, the genetic correlation between the numerator (e.g., dry matter intake, **DMI**) and denominator (e.g., average daily gain, **ADG**) is positive, and therefore, selection for improved FCR has resulted in cattle that grow faster, have increased mature size, and increased maintenance and feed requirements. Alternatively, efficiency measures that remove various known energy uses from feed intake, such as body weight and production, are now being used within breeding programs. Residual feed intake, also referred to as net feed efficiency is defined as the difference between an animal's actual feed intake and its expected feed requirement for maintenance of body size and production. It is genetically independent of body size and growth.

Q. How do you know if you are making progress over the years in feed efficiency if the average RFI value is always zero?

A. Your record keeping will be critical. First, a baseline year would be selected (e.g. 2014), which is very similar to plotting the genetic progress in any trait (e.g., 200-d weaning weight set at 450 lb in 1975). Then each successive year is compared to the baseline year so over time you can see how the average value has improved. Because RFI is a relatively new trait being selected for, you should contact your breed association for more details on establishing the average.

Q. I can't justify the purchase of expensive individual feed intake monitoring equipment for my ranch, so how do I get the benefit of RFI into my herd?

A. Many progressive producers and organizations have access to bull test facilities that include individual feed intake measurement. Seed stock producers with tested animals will offer these animals or their progeny through sales - making certain pedigrees known for their feed efficiency. You have the opportunity to



source and purchase these tested animals so their genetics get into your herd. The combination of research and commercial feed intake testing will accelerate progress in the industry. Even though the upfront cost of testing can be substantial, you will discover the potential returns on that investment to also be substantial. Because RFI is a moderately to highly heritable trait, it will be passed on to the progeny making the influence of a negative RFI (feed efficient) bull significant in your herd; whether you keep replacement heifers from him or feed calves for market.

Estimated Breeding values (EBVs) for RFI, as determined by seedstock associations, become more accurate and reliable as more animals are measured for feed intake and RFI. In addition, genomic/DNA information obtained from tissue and/or blood samples is being used to enhance the accuracy of EBVs such that young males and females can have moderate accuracy EBVs early in life.

Q. There must be one breed of cattle that is more feed efficient than some of the other breeds. So, which breed has superior feed efficiency?

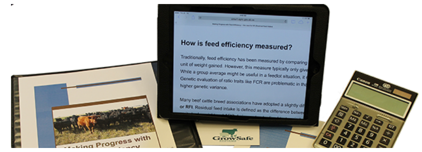
A. You have heard this before, but there is just as much variation within a breed as there is between breeds. Feed efficiency is no different. Variation in feed intake of two animals gaining at the same rate can be 35% or more. As an example, if a pen of 100 calves weighing 1000 lbs has an average individual intake of 25 lbs of feed, the expected range in individual feed intakes would be 20 to 30 lbs with no difference among gain in the calves. Your challenge comes in identifying the genetics for the animals that are below 25 lbs intake. With time, some breeds may be involved in more research and genetic selection for feed efficiency, making more pedigrees with superior feed efficiency known to the beef industry.

Q. Feed efficiency is just a measure of economic importance for the feedlot industry. How can I benefit from it as a cow/calf producer?

A. Feed efficiency is a measure of economic importance to any producer of cattle including cow/calf, backgrounding, feedlot and seed stock production regardless of being a purebred or commercial producer. Cattle that have lower feed intakes for an equal level of production will have reduced feed costs compared to those animals that have higher feed intakes. Because feed costs represent up to 70% of the production costs in a beef operation there are significant savings in determining which animals are the most feed efficient and then selecting for their genetics. This is particularly true for the breeding cow herd which is on a maintenance ration for the majority of their life and we want to maintain cattle with the lowest possible feed costs without sacrificing production.

Q. What are the disadvantages of measuring or selecting for RFI?

A. The cost of currently collecting the information for a particular group or individual animal can be substantial especially if you take into account that of all the animals on an RFI test, half will get a positive ranking (inefficient) and half will get a negative ranking (efficient). However, the associated feed costs of the inefficient animals will also be substantial if you retain them in your breeding program, so careful consideration to



how they are marketed needs to occur. In addition, reputation breeders that have tested over many years for RFI need to make potential customers aware if these are progeny from superior feed efficient sires. The progress that a breeder has already made because of numerous years of testing and genetic improvement may be exceptional compared to another breeder. This might make the inefficient (positive RFI) cattle attractive from the reputation breeder.

Also, RFI should not be used as single trait selection. Any good genetic and marketing program has more than one feature to impress potential customers. When performance and economics are considered, a superior growth, negative RFI and ideal conformation bull that does not pass the semen test should not be marketed for breeding purposes just as an inferior positive RFI bull with poor ADG who passes a breeding soundness evaluation should not be marketed for breeding either.

Q. Aren't efficient cattle smaller cattle because they have lower intakes compared to larger animals? Can't I just select for smaller sized cattle because my feed costs will be reduced just by doing so?

A. Feed efficient cattle selected through RFI have the lowest feed intakes for their performance and production. By just selecting for size you are not considering how much they are eating for their output or production. RFI estimates efficiency of use of feed consumed by subtracting observed dry matter intake of an individual animal from the dry matter intake predicted by an equation developed from the relationship between dry matter intake, daily gain and metabolic mean weight across fed contemporaries.

RFI is genetically independent of body size and growth, meaning that there are large animals that are efficient and small animals that are efficient at equal growth rates, just as there can be large inefficient and small inefficient animals.

This is the third in a series of fact sheets on RFI written by Dr. Susan Markus. The other titles are: "Making Progress with Feed Efficiency – the case for Residual Feed Intake (RFI)" and "The Economics of RFI".

For further information on feed efficiency go to Alberta Agriculture and Rural Development's home page www.agriculture.alberta.ca to search for RFI curriculum for cattle producers. Additional information can be found at www.livestockgentec.com and www.growsafe.com

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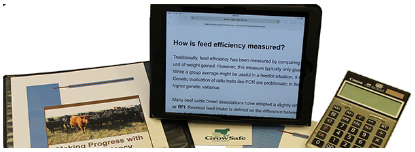
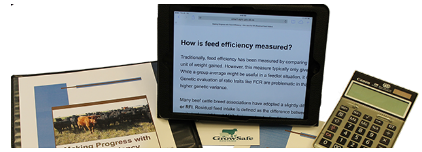
University of Alberta | University of Manitoba | livestock gentec | Manitoba Beef Producers | SCA Saskatchewan Cattlemen's Association | Alberta Beef
Agriculture Council of Saskatchewan Inc. | Investment Agriculture Foundation of British Columbia | MRAC Manitoba Rural Adaptation Council Inc. | Agriculture & Food Council of Alberta


How is feed efficiency measured?



Appendix 3 Test Your Knowledge

The following provides a summary of important questions for the livestock industry.

Use this list of questions as a guide to test your knowledge of the 10 modules in this curriculum.

1. What is residual feed intake (RFI)? ______________________________

2. Why is RFI important to the cattle industry? ______________________________

3. There are different ways to measure feed efficiency in cattle; explain why RFI should be used.

   ____

4. How is RFI calculated? ______________________________

5. What are some possible biological reasons for the differences in feed efficiency? ______________________________

6. How heritable is RFI? ______________________________

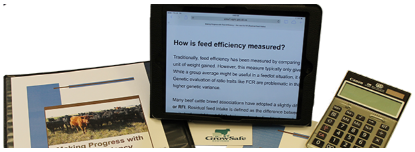
7. Are there any genetic tests to determine RFI for cattle? ______________________________

8. Can feed efficiency of cattle be predicted based on DNA and, if so, how accurate is it?

   ____

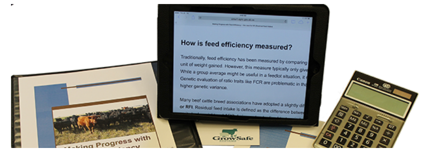
9. Does selection of cattle for feed efficiency through RFI affect other traits? ______________________________

10. Consider sustainability and the environment and explain if selecting cattle for RFI has advantages over selecting cattle for feed conversion ratio (FCR). ______________________________



Answers

1. Module 1-9.
2. Module 1-7 (*margin quote by Dr. Basarab*), Module 2-6 (*text box opportunity for beef producers*) and Module 7-3.
3. Module 1-10 and Module 4-11 (*text box RFI and Feed:Gain*).
4. Module 6-6 and Module 5.
5. Module 6-6.
6. Module 3-16 and Module 7-4.
7. Module 9
8. Module 3-10 and 3-18.
9. Module 4-12 and 4-13.
10. Module 4-16 and Module 8-3.



Glossary

ABC (across breed comparisons) adjustment factors that allow producers to compare the EPDs for animals from different breeds for specific traits; these factors reflect both the current breed difference and differences in the breed base point. They should only be used with current EPDs because of potential changes in EPD calculations from year to year.

Accuracy refers to how well an estimate of the genetic merit (e.g., EPD, or DNA-test result) predicts the true genetic merit of an animal. Accuracy values can range from 0 (in which case the estimate has no relationship to an animal's true genetic merit) to 1 (in the theoretical situation where the estimated breeding value is equal to the true breeding value). In practice, accuracy values never reach the theoretical limit of 1, although very high accuracy of extensively used AI sires can reach 0.99.

ADG (average daily gain) is the amount of weight gain an animal expresses on a daily basis. For example, an animal on June 1 weighing 310 kg and then weighed again on June 30 at 335 kg would have an ADG equal to 335-310= 25 divided by 30 days =0.83 kg/d ADG.

Beta-adrenergic agonist (β-adrenergic agonist) are feed additives with specific withdrawal times first approved for use in beef cattle in 2004 under the names of Optaflexx™ and Zilmax™ that repartition the energy from feed to increased muscle instead of fat.

BLUP (best linear unbiased prediction) is a mathematical model that estimates the genetic merit of an animal, while simultaneously accounting for environmental effects and other possible genetic and non-genetic effects.

BWT or **BW** (body weight) is the weight of an animal reported in either kg or lb.

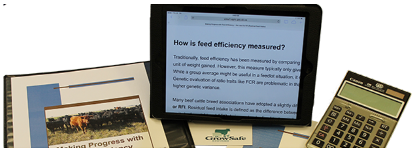
CE (calving ease) is an EPD expressed as a percentage of unassisted births, with a higher value indicating greater calving ease in *first-calf heifers*. It predicts the average difference in ease with which a sire's calves will be born when he is bred to *first-calf heifers*. Ideally, you should take both the calving ease EPD and the birth weight EPD into account when selecting animals with improved calving ease.

CEM (calving ease maternal) is an EPD expressed in percentage unassisted births with a higher value indicating greater calving ease in first-calf daughters. It predicts the average ease with which a sire's daughters will calve as first calf heifers when compared to daughters of other sires. Ideally, you should take both the calving ease EPD and the birth weight EPD into account when selecting animals with improved calving ease.

CH_4 refers to methane gas. Ruminants, which include cattle, buffalo, sheep and goats, have a large fore-stomach where methane-producing fermentation occurs. Water vapor, methane, carbon dioxide and nitrous oxide are the four primary greenhouse gases.

CO_2e (carbon dioxide equivalents) relates to the effective concentration of all the greenhouse gases. It is derived by summing the total amount of atmospheric warming from all the greenhouse gases and expresses the sum in terms of the equivalent amount of CO_2 needed to give that same warming.

Conformation refers to the visual appraisal, structural soundness and overall appearance of an animal or carcass.



Contemporary group is a set of animals that have had an equal opportunity to perform (same sex, managed alike, etc.) and have been exposed to the same environmental conditions and feed resources.

Correlation is the measurement of the strength and direction of a linear relationship between two variables. A correlation greater than 0.8 is generally described as strong, whereas a correlation less than 0.5 is generally described as weak.

CP or **crude protein** is a measure of the nitrogen content of a feed.

DM (dry matter) is a measure of feed when completely dried as opposed to an *as-fed basis*, which includes the moisture content. Dry matter content of a feedstuff is important because it reveals the actual amounts of various nutrients available to the animal consuming the feed and allows us to make direct comparisons between different feed types.

DMI (dry matter intake) is the amount of feed an animal consumes per day on a moisture-free basis.

DNA (deoxyribonucleic acid) is the hereditary material in humans and almost all other organisms. It carries the genetic information in the cell and is capable of self-replication and synthesis of RNA.

Docility refers to an animal's temperament, those that are easily managed or handled. Calm cattle have been found to eat more, have better responses to vaccination and preconditioning programs and produce more tender carcasses.

EBV (estimated breeding value) is the genetic merit of an animal whereas an EPD (expected progeny difference) is the genetic merit of an animal as a parent. Given that an animal can only pass on a sample half of its alleles to the next generation, the relationship between the two is as follows: EPD=½(EBV).

EFI (expected feed intake) is the amount of feed an animal is expected to consume based on its weight, performance level and backfat.

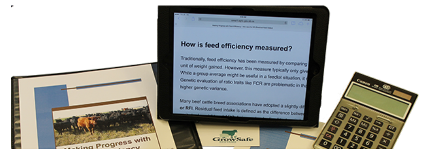
Enteric fermentation is the process in which ruminant livestock produce methane through their digestion. Since methane represents a loss of carbon from the rumen and, therefore, an unproductive use of dietary energy, scientists have been looking for ways to suppress its production.

EPD (estimated progeny difference) is the genetic merit of an animal as a parent whereas an EBV is the genetic merit of an animal. Differences in EPDs between two animals of the same breed, mated similarly, predict differences in performance between their future offspring. Remember that EPDs include the performance of the relatives of the animal, as well as its individual performance.

FCR (feed conversion ratio) is a measure used to evaluate the amount of feed mass consumed to produce body mass. Typically cattle convert 5 to 6 lb. feed into 1 lb. meat (FCR = 5:1). However, many factors like physiological status of the animal, nutrient content of the feed and environment can influence this value. A lower value is preferred.

FE (feed efficiency) a measure of how efficient an animal is at converting feed to body mass. It can be measured in many different ways including FCR or RFI.

FI (feed intake) is a measure of the amount of feed an animal consumes over a defined period of time.



Genome is an organism's complete set of DNA. The size of the bovine genome is 3 Gb (3 billion base pairs). It contains approximately 22,000 genes of which 14,000 are common to all mammalian species.

Genomics is the field of science that studies an organism's entire genome (DNA sequence). Genomics analyzes the relationship between genetics and traits, and uses the data to answer scientific questions and solve practical problems.

Genotype is the genetic makeup of an animal. It can be considered as the blueprint for building the animal.

GHG (greenhouse gases) are gases like water vapor H_2O, carbon dioxide CO_2, methane CH_4 and nitrous oxide NO_2. Greenhouse gases are thought to absorb energy, slowing or preventing the loss of heat to space, resulting in warming the earth and contributing to climate change.

Heritability is the proportion of observed differences on a trait among individuals of a population that is due to genetic differences.

Ionophores are feed additives classified as antibiotics used in cattle diets to increase feed efficiency and body weight gain; they are commercially known as Rumensin®, Bovatec® and Cattlyst®. They also decrease the incidence of bloat, coccidiosis and acidosis in cattle.

IRT (infrared thermography) is an infrared imaging science that is capable of detecting radiation in the infrared range of the electromagnetic spectrum and produces images allowing one to see temperature variations in an object. These thermal images can be used to detect illness, disease or, more recently, explore utility in determining feed efficiency status of cattle.

Linkage is where parts of the genome that affect different traits are inherited together.

Maintenance energy is the energy required by an animal for a maintenance condition which means when it is not producing or reproducing and when body weight and condition are stable.

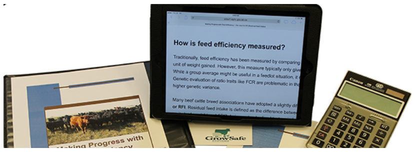
MAR (marbling) is the flecks of fat in the ribeye muscle between the 12th and 13th ribs of a beef animal. Increased marbling results in higher carcass quality grades. Marbling can either be assessed in the carcass or with ultrasound measurements in a live animal reported as a percentage intramuscular fat (%IMF) in the ribeye muscle.

MBV (molecular breeding value) is a genetic evaluation of an animal consisting of SNP effects estimated using a set of training data, genetic correlation using a set of validation data and a prediction of EPDs using a set of evaluation data.

Methane or CH_4 is produced through enteric fermentation. Ruminants, which include cattle, buffalo, sheep and goats, have a large fore-stomach where methane-producing fermentation occurs. Water vapor, methane, carbon dioxide and nitrous oxide are the four primary greenhouse gases.

MGA (melengestrol acetate) is a feed additive commonly used in feedlot heifer rations to stop estrus activity or to synchronize estrus to shorten a breeding season.

Mutation is a change in the sequence of the genome of an animal and is the result of damage to DNA. Mutations in genes can either have no effect, alter the product of a gene or prevent the gene from functioning properly or completely.



N_2O (nitrous oxide) is a naturally occurring atmospheric gas. Water vapor, methane, carbon dioxide and nitrous oxide are the four primary greenhouse gases.

Phenotype is the observable structure, function or behavior of an animal resulting from the interaction of its genotype with the environment.

Physiological status is the condition or state of the body or bodily functions. It is important when grouping cattle into contemporary groups that we have a similar physiological status like male vs. female, similar growth curve with age and non-pregnant during a feed efficiency test.

Pleiotrophy is when the same part of the genome (or genetic code) affects different traits.

Prophylactics are a treatment designed and used to prevent a disease from occurring. As an example, research using genomics is working toward new discoveries to reduce the use of prophylactics like medicated feeds for animals.

PTA (predicted transmitting ability) is the average genetic value for a given trait that an animal transmits to its offspring.

R^2 or **r^2** value or coefficient of determination explains the variation among variables you are looking at. For example, if $r = 0.922$, then $r^2 = 0.850$, which means that 85 percent of the total variation in y can be explained by the linear relationship between x and y (as described by the regression equation). The other 15 percent of the total variation in y remains unexplained.

REA (ribeye area) is used as an indicator of the lean meat yield of a carcass; it is the area of the longissimus muscle at the 12^{th} rib on the beef forequarter. It can be measured by ultrasound on a live animal or by cutting into a carcass on a slaughtered animal.

Repeatability is the variation in measurements taken by a single person or instrument on the same item and under the same conditions.

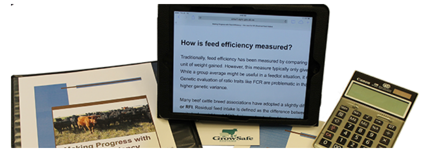
RFI (residual feed intake) or net feed efficiency is defined as the difference between an animal's actual feed intake and its expected feed requirements for maintenance and growth. RFI is the variation in feed intake that remains after the requirements for maintenance and growth have been met. Efficient animals eat less than expected and have a negative or low RFI, while inefficient animals eat more than expected and have a positive or high RFI.

RFID (radio frequency identification) is a passive electronic identification animal ear tag that contains a unique chip number and transponder which is activated when introduced into an electromagnetic field produced by an RFID reader. RFID tags are required by the GrowSafe feed intake monitoring system.

RG (residual gain or R-ADG residual average daily gain) is defined as the difference between actual weight gain and the gain predicted on the basis of dry matter intake, maintenance of body weight and fat cover. Animals with a positive R-ADG value are favored because they have higher daily gains for the amount of feed consumed and their body composition (% fat).

RIG (residual intake and gain) combines RFI and RG to identify fast-growing animals consuming less feed than expected, while still being independent of body weight.

SC (scrotal circumference) usually expressed in centimeters, it is the measurement of the circumference of the bull's scrotum.



SNP (single nucleotide polymorphism) is a change in which a single base in the DNA differs from the usual base at that position. They can act as biological markers, helping scientists locate genes that are associated with cattle performance or disease susceptibility.

Subcutaneous fat is the fat that accumulates under the skin as backfat or also known as external fat when discussing carcasses. It can be measured by ultrasound in a live animal.

Variance measures how far a set of numbers is spread out. It describes the distribution of a population of numbers.

WW or **WWT** (weaning weight) is the weight of a calf at weaning time from its dam. The weaning weight EPD is a predictor of a sire's ability to transmit weaning growth to his progeny compared to that of other sires.

YWT or **YW** (yearling weight) is the weight of an animal at a year of age. The yearling weight EPD is a predictor of a sire's ability to transmit yearling growth to his progeny compared to that of other sires.