Innovation in Cattle Feed Efficiency

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Defining Efficiency

Traditionally, cattle producers would likely agree that measures of outputs like pounds of calf weaned per cow exposed, calf weaning weight as a % of the cow weight or feed:gain for backgrounding or feedlot operations are measures of efficiency. These factors can be translated into the resulting $/lb weaned calf to establish profitability of a cow herd or cost per pound of gain in a feedlot.

Beef cattle need to be efficient from many perspectives, meaning definitions related to single traits can be misleading. Efficiency is a multi-trait selection effort. If only one trait defines the efficient aspect of the animal, then high production may be compromised somewhere else. Take the dairy cow, for example, while she may excel in high production for milk, she is certainly not excelling in high fertility or structural correctness of feet and legs for any extended period of time. The same is true of the beef animal. Feed efficient cattle are more than just those who have the greatest daily gain relative to their daily feed intake because we expect cattle that eat more to gain more, however, this is not always the case. Feed efficiency is equally important for the cow herd just as it is for the feedlot herd.

We should also not forget efficient beef should be sustainable beef. After a year and a half of negotiations, a global definition for sustainable beef has been approved by 96% of the Global Roundtable for Sustainable Beef (GRSB) members. They have agreed it’s socially responsible, environmentally sound, and economically viable; and it must come from systems that prioritize planet, people, animals, and progress.

The cow herd of 2007 is more efficient compared to the cow herd of 1997 as the same amount of beef now requires:

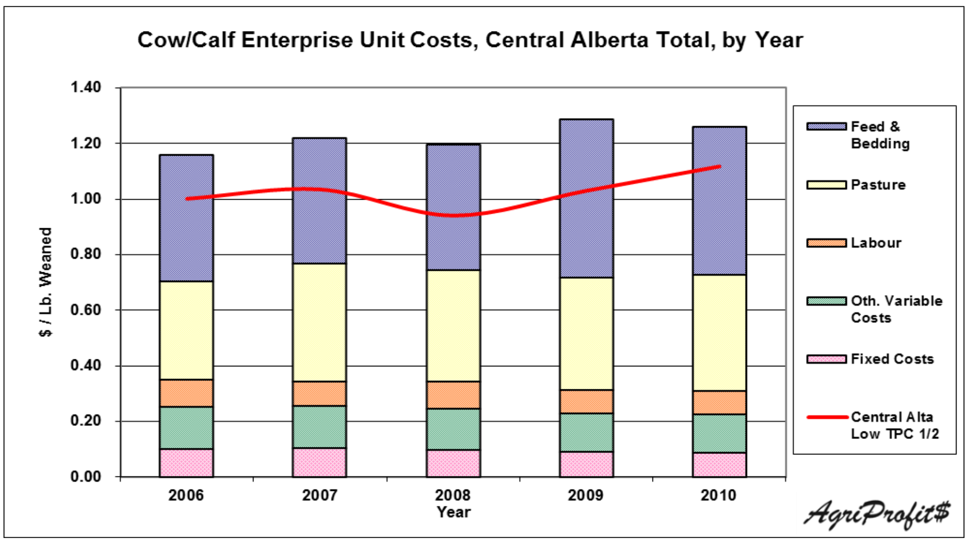
- 70% of the animals,
- 81% of the feed,
- 88% of the water,
- 67% of the land
- resulting in a 16% decrease in the carbon footprint of beef

(Capper 2011, Animal Frontiers)

Costs of production

When 56-71% of the total cost of production for cow-calf operations is associated with feed, bedding and pasture, and maintenance requirements of breeding cattle make up 65-75% of the total dietary energy costs, it results in over 40% of your costs of production being impacted by feed efficiency (Figure 1, ARD 2012). Only through genetic selection for those animals with improved feed efficiencies will profitability in the cow herd improve once costs of production have been streamlined. For the backgrounder or feedlot, the technologies that improve digestibility and ration formulation will ultimately lead to improvements in feed efficiency.

Figure 1. Cow calf enterprise unit costs, Central Alberta total by year 2008-2010



(ARD, 2012)

What defines an efficient beef cow?

The common factors in the cow efficiency debate are fertility, size and dry matter intake. Fertility is largely about management and nutrition. Assuming we balance our cow herd with our resources (feed, labour, health protocols etc.) we would expect to get a live calf from every cow exposed to a bull in a reasonable time period of 45-60 days. The next factor, size, tells us that bigger cows can raise bigger calves – to a point. Larger cattle eat more and ultimately have higher feed intakes and costs of production.

It is the final factor, dry matter intake that looks at the inputs rather than outputs of a beef operation. While many aspects can impact feed intake, feeding behaviours and ultimately feed efficiency - defined as a feed conversion ratio listed below, the intent in this discussion is to examine innovations that don't only look at performance in a growth phase, but consider the maintenance requirements of replacement breeding animals and mature cattle when defining feed efficiency.

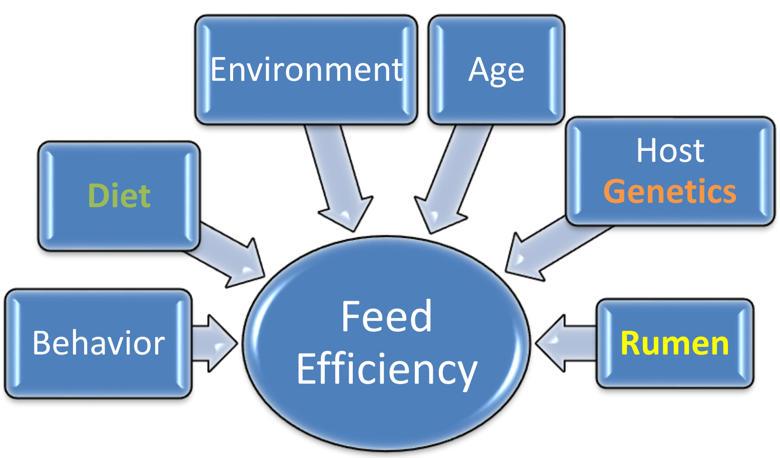
- *Genetics*: certain pedigrees are more feed efficient than others; increased inbreeding makes Feed:Gain poorer.

- *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 results in poorer Feed:Gain.
- *Parasites:* an increase of internal parasites, flies and ticks make Feed:Gain poorer.
- *Grain in the Ration:* higher levels of grain and concentrates in the ration, over 85 percent, generally improve Feed:Gain.
- *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.

(Markus, 2014)

Innovations to improve feed efficiency

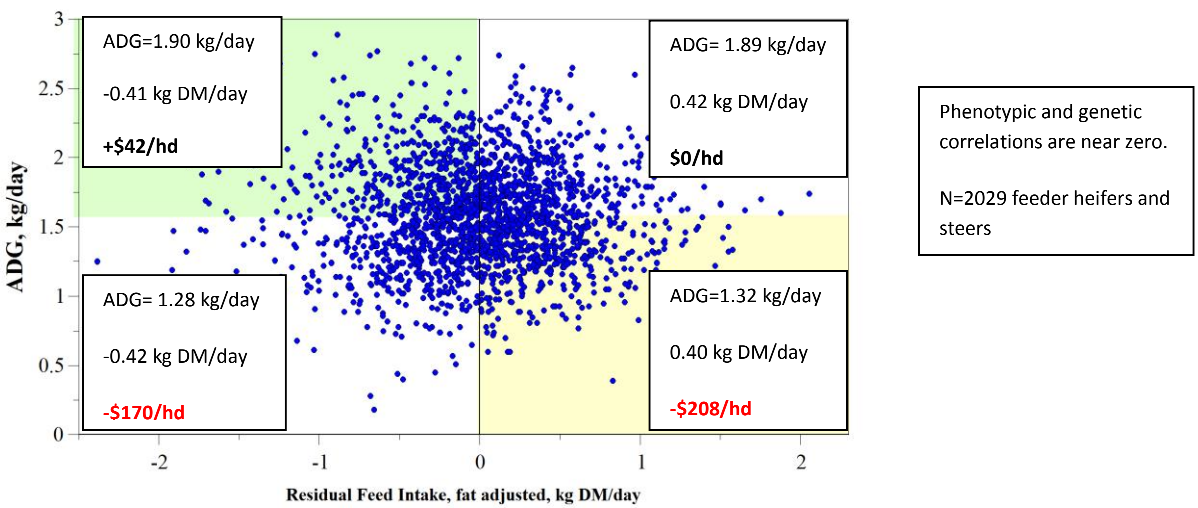
New research areas and innovations highlighted in this paper will be related to animal genetics, rumen microbiome, diet formulation and improved digestibility of crops.



1. Genetic selection for RFI

Cattle, regardless of size, can be ranked based on the trait of residual feed intake (RFI). RFI is defined as 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, feed efficient animals which have negative or low RFI values, consume less feed than expected without compromising their production level. RFI does not favour larger animals that gain more. It is independent of body weight and growth, meaning you can find feed efficient animals that also gain well. The quadrants of feed efficiency and gain are shown below (Figure 2). Selecting animals with the genetics of those in the upper left quadrant and to cull those in the lower right should be our goal.

Figure 2. Correlation between growth and animal size



Note: same feeder cost and price, transportation, vet, medicine, interest, yardage, death loss and marketing costs. (Arthur et al., 2001; Basarab et al., 2003; Crews et al., 2003; Jensen et al., 1992 and Basarab et al., 2013)

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 – less efficient and less sustainable.

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
- Reduce feed intake at equal weight and ADG
- Improved feed to gain ratio by 10-15 percent
- Reduced net energy of maintenance and reduced methane and manure production by 10-15 percent (reducing the carbon footprint of cattle)
- Little if any effect on age at puberty

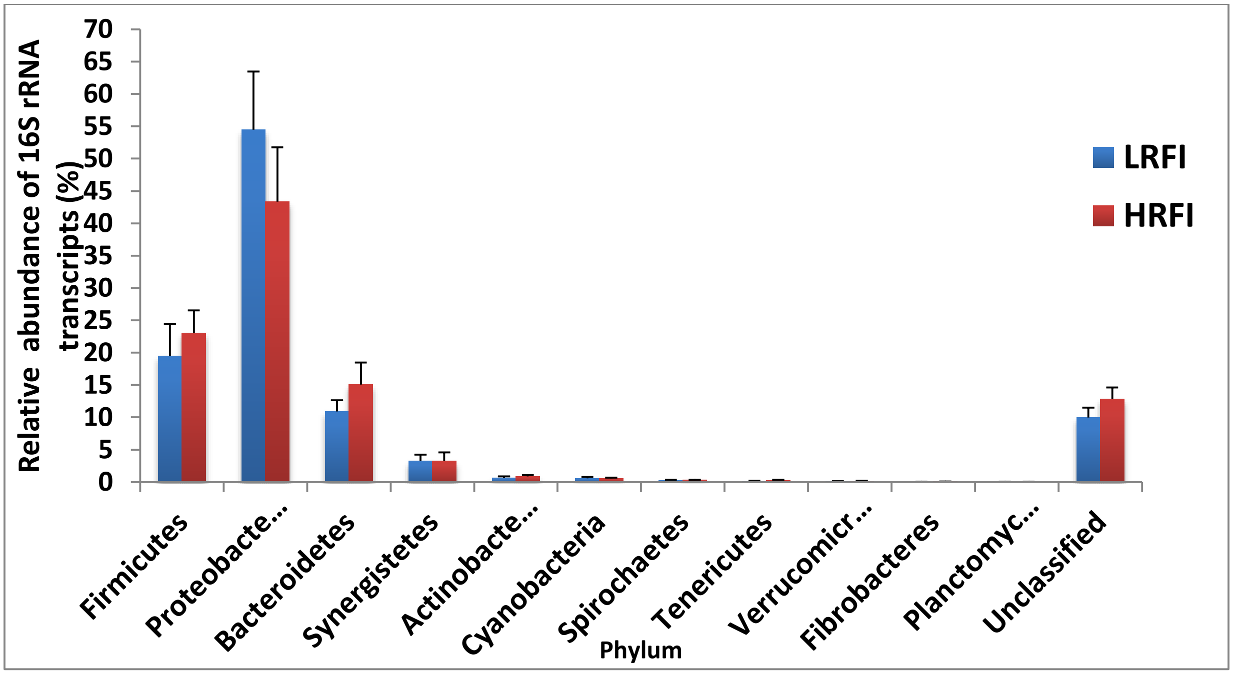
- No negative effect on pregnancy, calving or weaning rate
- Little effect on bull fertility
- Positive effect on body fatness or weight particularly during stressful periods
- Reduced feed costs by: $0.07-0.10/hd/d feeders and $0.11-0.12/hd/d in cows.

2. Improved Gut Environment

Because fecal energy is generally the primary loss of energy in diets fed to cattle, any advantage an animal has in diet digestibility relative to the population would be manifested as improved FCR because of reduced fecal energy loss. Understanding which rumen microbes are responsible for improved digestibility and ultimately feed efficiency, so that gut environment manipulations can be made through nutrition and management is a promising research area.

Functional and compositional variation of the rumen microbiome exists between feed efficient and feed inefficient cattle (Figure 3). Efficient cattle displayed higher carbohydrate metabolism and lower methanogenesis. Current unpublished research at the University of Alberta (Guan and Kong) revealed epithelial attached microbiome differed between high and low RFI animals when RNA-sequences were analyzed. Low RFI (feed efficient) epithelium showed greater activity of ureolytic – more microbial nitrogen recycling and oxygen scavenging bacteria. Also, different microbial families may be less active in efficient animals as shown by their lower populations from a metatranscriptomic analysis.

Figure 3. RNA-seq analysis revealed epithelial attached microbiome differed between high and low RFI



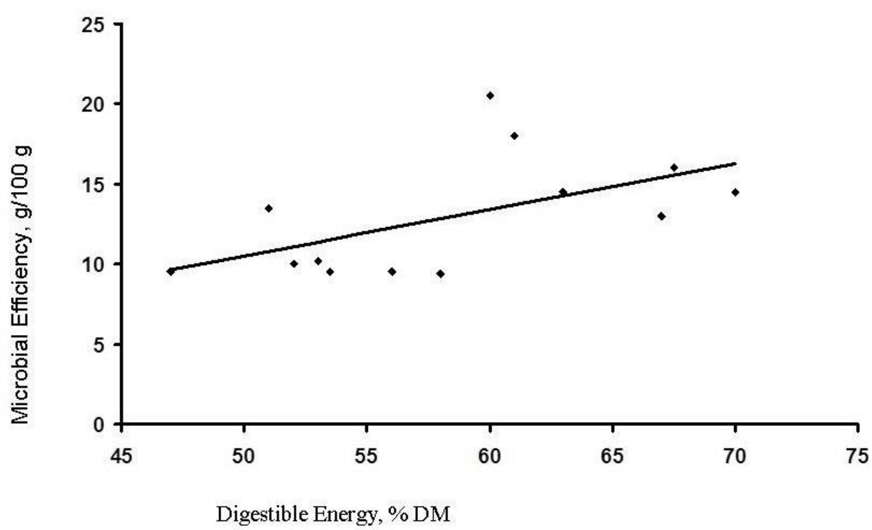
Kong et al., unpublished data

3. Improved Diet Formulation

Rations formulated for the cow of 1997 will not be the same for the cow of 2017. Increasing adoption of genomic tools, especially those that put emphasis on selection for feed efficiency with RFI means cattle genetics are improving. Feed efficient animals are those with an advantage in energy conservation. The energy required for growth is assumed to be a function of the energy consumed above maintenance energy requirements. While NRC estimates, on average, are accurate for a group of cattle on feed, a large variation for metabolic efficiency exists within a population of animals. For example, metabolic energy for a group of steers ranged from 9.5 to 19.7 MCal ME/kg of gain on the same diet meaning the average of 14.6 would be accurate if cattle genetics did not improve for feed efficiency. Thus, the nutrient density in the diet would be expected to change as efficiency and intake of the animal changed to ensure all nutritional requirements were met (Kerley, 2012). This will have implications for cattle on high growth rations that will demand an absorbable amino acid supply above their microbial supply. Also, improvements in fibre digestibility may mean lower inclusion rates of high cost energy sources (grains) for the beef cow.

Fermentability of fiber and other carbohydrates drives microbial protein synthesis (Figure 4). Consequently, factors that increase rumen fiber digestibility can have a large impact on microbial protein production. If a greater percentage of the total dietary energy from forages was available to ruminants, lower cost diets could be formulated leading to more efficient use of environmental resources.

Figure 4. Improvement in microbial efficiency as a result of increased digestible energy.



(Patterson et al., 2006)

A recent example of new diet formulations is from DSM Nutritional Products Ltd., the University of Alberta, Livestock Gentec, the Alberta Livestock and Meat Agency and Agriculture and Food Canada whom have partnered to reduce dairy and beef cattle greenhouse gas emissions, improve animal performance and health, and reduce input costs for producers by creating and testing a non-antibiotic feed additive. Changes in gut microbiota and the links it has to performance and health were examined. After two years of animal trials and results, including demonstrating up to 60 per cent reduction in methane emissions in dairy cattle, increased feed efficiency while maintaining nutrient digestibility, and immune competency and health, the project will soon head to commercialization. Such feed additives may have a positive impact on ration formulation for ruminants.

4. Crop selection and breeding for improved digestibility

In the past, improved nutrient digestibility of plants and grains, resulting in improved FCR, has advanced through physical processing (grinding, pelleting, steam rolling or/flaking). Chemical treatment of forages (ammoniation and oxidants) improves cellulose and hemicellulose digestion in the rumen and has also shown promise. Starch from grains used to be a cheap source of energy, but this is no longer true due in part to competition for starch from the ethanol industry. Livestock producers are being forced to look for alternate sources of energy and will need to consider how to get more energy from fibre. Thus, the implications of newer crop varieties with greater fibre digestibility will mean lower inclusion rates of high cost grains, thus impacting ration formulation.

The future in plant genetics is to selectively breed for improved digestibility as it shows promise that altering the starch form can improve digestibility. Genotype and environment effects on in vitro forage digestibility of triticale and barley breeding lines in the prairie provinces have been studied since 2008 (Table. 1). Research into what is happening at the plant level that leads to changes in the digestibility in barley and triticale as lignin and starch are laid down is ongoing.

Table 1. Analysis of variance for IVFD of barley and triticale forage grown at Lacombe, AB and Dawson Creek, BC.

Source of Variation	Barley	Triticale
	2008	
Genotype	4.852***	6.592***
	2009	
Environment (E)	17.773**	0.000
Genotype (G)	9.329***	5.878**
G X E	2.560	4.260*
	2010	
Environment	59.912*	475.207***
Genotype	8.267	9.369***
G X E	4.056	2.382
	2011	
Environment	14.31***	397.311***
Genotype	2.06**	7.200**
G X E	1.21	4.672*

*, **, *** Significant at the 0.05, 0.01, and 0.001 levels of probability respectively.

(Juskiw, 2015)

In the past, forage lines were assessed from phenotypic performance, disease resistance and minimal quality data. Now, the combination of rapid quality analysis of forage samples with NIRS (near-infrared reflectance spectroscopy) and the application of that data to estimate values of economic return based on both quality and yield is possible. Forage varieties will be able to be chosen based on dry matter yield, average daily gain and cost of gain in a backgrounding situation, or by dry matter yield, carrying capacity and daily feed cost for a swath grazing situation (Juskiw, 2015).

Traditionally, the fiber content of forages has been measured using acid and neutral detergents. Acid detergent fiber (ADF) is comprised of cellulose and lignin. Neutral detergent fiber (NDF) includes cellulose, hemicellose and lignin. Lignin is the component of fiber that is least likely to be degraded in the rumen. Different types of lignin have differences in solubility and digestibility (Jung and Lamb, 2003). While grasses typically have higher NDF contents than alfalfa, they can have a higher feed value due to better digestibility of their fiber (Jeranyama and Garcia, 2004). Small grain cereals usually have greater digestibility of their leaves compared to species such as corn. The relationships of traditional methods of measuring fibre in silage have come under rigorous scrutiny in recent years with the finding that these methods have little relationship to actual fibre digestion in the rumen (Rick Corbett and Pat Juskiw, personal communication). In alfalfa, the correlation of ADF with in vitro fiber digestibility (IVFD) was found to be only 0.55 (Undersander, 2002) while in corn, the correlation was only 0.10 (Oba and Allen, 2005). Forage IVFD is so poorly correlated with NDF or crude protein (CP) content that it is not possible to estimate it from these quality traits (Oba and Allen, 2005). The National Research Council (NRC, 2001) recommends that forage

digestibility for dairy cattle be based on lignin or IVFD rather than ADF. Thus, the intent of Juskiw et al.'s project was to confirm the genetic component of IVFD in small grain cereals; develop a rapid and effective measurement of IVFD using near infrared reflectance spectroscopy (NIRS); and determine intrinsic quality differences in small grain cereal forage due to IVDF rather than RFV. These studies will revolutionize how we measure, select for, and maximize productivity from small grain cereal forage.
The Juskiw research team has discovered methods to measure fibre digestibility, the relationships between this trait and other forage, agronomic and grain quality traits, and they have made crosses and advanced promising material directly into their active breeding programs. The team will continue to study this trait and will release new varieties with improved fibre digestibility that will enhance the productivity of the ruminant livestock industry.

Summary

Innovations in feed efficiency are focused on the improved genetics of both animals and the plants they consume. Feed efficiency, as measured by feed conversion ratio, could be improved by 5% or greater by increasing digestion through plant breeding and selection. Additive to this is the potential for another 10-15% improvement in feed efficiency as a result of selection for cattle with the trait of low residual feed intake (negative RFI) which are also shown to have functional and compositional differences in their rumen microbiome compared to feed inefficient cattle. Under ideal conditions, these efficient animals and improved feed sources could take advantage of ruminant nutritionists with the knowledge to formulate diets and create feed additives that allow their genetic potential of efficiency to be expressed, thus adding to this feed efficiency improvement. The time has come for research in improvements to fiber digestibility in both the animal and plant so that the ruminant livestock industry can remain competitive and sustainable.

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