Priority Area Review:
Feed Grains & Feed Efficiency

June 2017

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ACKNOWLEDGEMENTS

Thank-you to all the researchers and editors to contributed their expertise and time to writing sections for this project. This would not have been possible without you.

- Darryl Gibb
- John McKinnon
- Karen Beauchemin
- Ross Mackenzie
- Tim McAllister

EXECUTIVE SUMMARY

In 2012, the Beef Cattle Research Council (BCRC) committed to completing an evaluation of the value of research funded in each priority area: Beef Quality & Food Safety, Forage & Grassland productivity, Animal Health & Welfare, Feed Grains & Feed Efficiency. The goal of these priority area reviews was to provide a cost:benefit analysis of research to identify research areas within each priority that were potentially under- or over-funded. This is intended to inform the next round of priority setting sessions by providing more in-depth background for the participants.

Why invest in feed grains and feed efficiency?

There has been much discussion globally about how agriculture will meet growing demand for animal protein in an environmentally acceptable manner. Exponential growth in global human population and a general increase in per capita consumption of animal products require technologies that will produce more animal protein while using fewer natural resources (i.e. feed, water) and reducing negative environmental impacts such as emitting fewer greenhouse gases (GHGs). The National Beef Sustainability Assessment (CRSB, 2016) indicates that after enteric methane, feed production and manure are the next largest contributors to GHG emissions. Research around feed grain production and utilization can make a major contribution to environmental sustainability of the Canadian beef industry.

Feed represents a large proportion of total beef production costs. Investments in feed grain and feed efficiency is crucial for the beef industry because feed grain availability, feed costs and feed efficiency all have significant implications on the industry's economic sustainability, competitiveness in the global market, as well as producer profitability.

Improved feed efficiency is associated with both positive economic and environmental benefits. For each percent reduction in feed intake (kg as fed/day) is associated with an average 2.3% increase in net returns and 33.46 tonnes reduction in emissions at the end of the feeding period (Boaitey et al. 2017).

While there have been significant improvements in feed efficiency over the years that have contributed to greater consistency in animal performance there are still gains to be made. Boaitey et al. (2017) reports feed efficiency scores ranging from a -4.02 kgs (as fed/day) below the control (these are the most efficient cattle) to 4.16 kgs (as fed/day) above the control (least efficient) on 5,600 cattle assembled from different experimental studies[1] – implying there are significant gains yet to be made in the beef industry.

Further improvements are critical to keep beef production competitive with other animal proteins that have much better feed conversion rates and consequently have a lower environmental footprint as fewer natural resources are needed to produce a kilogram of protein. However, it must be recognized that the majority of feed over the lifetime of a beef animal is forage that cannot be utilized by humans and therefore comparisons based on feed conversion are misleading.

OVERARCHING OBJECTIVE for FEED GRAINS & FEED EFFICIENCY:

Improve feed efficiency through the identification and validation of economical methods of identifying seedstock with improved feed efficiency and the development of alternative feeding strategies. Feed efficiency involves both the feed (nutrient composition, processing, etc.) as well as the animal (ability to extract and use these nutrients).

[1] Different experiment setting may contributes to this variation.

Feed Grain Production

New corn varieties that require fewer Corn Heat Units (CHUs) in the growing season have made it possible to grow corn in the irrigated regions of the prairie provinces. Economic and nutrition studies show that these new corn varieties can be a competitive crop option for cattle producers. With new corn varieties, corn for grain acreage in the prairie provinces has expanded 76% in the last ten years, and fodder corn acreage has expanded 61%. Despite rapid expansion of corn area, the adoption of corn in western Canada faces a number of challenges including: CHU requirement, water requirement, high input cost, labour and processing facilities. The area in corn for grain and corn for fodder accounted for less than 1% of the total farm land in Western Canada in 2016.

Current research is working on developing corn hybrids suited for the Prairies. The two areas of focus are to develop new varieties that mature within the cooler and shorter Western Canadian growing season and reducing the moisture requirement (i.e. improve drought tolerance).

Despite the fast expansion and great potential of corn production, local feed supply remains highly reliant on barley, which can be grown in areas that are not suitable to current corn varieties. Even in the future there will be areas that cannot produce corn, and barley will be needed to supply the feedlot industry. Hence, research on feed barley and barley silage remain crucial to the cattle industry. While there is little incentive for private companies to invest in barley breeding, there are studies funded by producers and government, covering topics such as improved grain yields, malting characteristics, disease and lodging resistance and feed quality traits.

Feed wheat and wheat silage is also an important feed source in Western Canada. It is recommended that wheat should be limited to 40 percent of the total diet to prevent or reduce the risk of digestive upsets (Lardy and Dhuyvetter, 2016). But recent studies (e.g. Wiese et al. 2017) indicate that cattle can be successfully transitioned to wheat-based finishing diet with PH effects of a relatively mild severity, if it's done carefully and slowly. Ergot, vomitoxin and other deceases or damages affect the nutritive value and safety of feed wheat. Science based recommendations for ergot alkaloid levels in animal feed is generally lacking, effective new technologies are required to either reduce the occurrence of the ergot in grains or reduce the toxicity of alkaloids for livestock (Coufal-Majewski et al. 2016).

Alternative feed grains like Dried Distiller Grains (DDGs) need to be addressed as they become available in the marketplace. When weathered grain crops become feed grade, there is also a question on when are they no longer even useful for feed. There are questions on how to handle/store product to ensure quality and consistent feed for cattle, and the proportion of the diet it can represent before negatively impacting animal health and performance. Currently the most prevalent issue has been quality issues with feed grains particularly mycotoxins (i.e. ergot, fusarium). Research has shown that contamination of feed with mycotoxins costs producers $5 billion in the U.S. and Canada alone (Robens & Cardwell, 2003). There is also a need for study on the causes of mycotoxin production as feed can be moldy with no mycotoxins, or appear to have no mold but have mycotoxins. There is a role for technology transfer of existing information and resources; and facilitating research on alternative feed resources.

Grain processing is an important step to optimize digestibility of grains, but processing grains too finely can lead to acidosis. Research on barley feed grain suggested that digestibility of barley grain by cattle is affected by factors such as the extent of gain processing, processing method, starch level of the grain. The extent of grain processing can be quantified as Processing Index (PI). While PI impacts grain digestion and animal performance, using only PI as a measurement for extensity of grain processing may not be reliable as commercial feed barley has a wide variation in quality and particle size.

As kernel uniformity makes it difficult to obtain optimal utilization of barley grain through traditional processing methods (e.g. dry rolling), screening of blended barley into more uniform fractions and precision processing of each fraction could increase intake of digestible nutrients for feedlot cattle (Yang et al. 2013).

The development in Near-infrared spectroscopy (NIRS) technology makes it possible to predict fecal composition and diet digestibility without requiring samples of the diet or estimates of intake. Using NIRS, McAllister et al. (2014) reported that reducing the PI of barley from 85 to 75 resulted in a decrease in fecal starch of 10%, leading to a savings of $4.50/head over a 120-day finishing period, and suggested that there is plenty of opportunity for feedlot producers to utilize NIR to estimate fecal starch and adjust processing accordingly to maximize starch utilization.

Future research in grain processing is needed to develop a simple way to rapidly and concisely determine the feed value of blend barley. Prediction model to quickly determine the feeding value of processed barley will allow producers to optimize processing and modulate starch fermentation in the rumen for improving animal health and performance (Yang et al., 2015). There is also research opportunity in developing an acidosis index of grain to predict acidosis risk of different barley samples (Yang et al., 2015). Economic research on the cost and benefit of different grain processing strategies and their relationship with cattle performance and acidosis risks. Since barley must be processed for efficient use be cattle, response to grain processing should also be one of the selection criteria to considered in breeding programs.

A couple of feedlots in western Canada have installed steam-flakers for barley. Steam flaking was not a commonly used processing method for barley in western Canada as it associated with higher costs. However, if the improvement in animal performance or feed efficiency more than offsets the additional costs, steam flaking could be an economical option. The economics of steam-flaking barley and how cattle respond to steam flaked barley has not been well understood. More research is needed in this area.

Another possible technology transfer approach is a grid pricing system that provides price signal for suppliers. In addition to buying on a bushel weight basis, feedlots could pay premiums or discounts based on a plumpness index. For example, 90% plus plump gets a premium, 85% or less gets graded levels of discount.[2]

Feed Efficiency

Bunk management typically refers to strategies of feed delivery that help achieve optimum, stable intakes of all cattle while maintaining digestive health. Managing acidosis is a perpetual challenge for finishing yards that have economic incentive to minimize forage use. Sub-acute acidosis contributes to bloat, reduced intake, liver abscess, and laminitis. A+ liver abscesses alone have been estimated to cost the U.S. feedlot industry an average of $7.42 per animal fed (Schmidt et al. 2002). The 2010/11 National Beef Quality Audit in Canada estimated liver discounts at $9.36 per fed animal or a total of $29.9 million for the industry in 2011[3]. Estimating total acidosis related costs at twice this value is likely conservative.

Although there have been several trials documenting the effects of feed delivery on rumen pH (Cooper et. al. 1999); research trials reporting positive effects of bunk management on performance are rare. The development of acidosis index of grain to predict acidosis risk of different barley samples could be valuable for the industry. Economic research on the cost and benefit of different grain processing strategies and their relationship with cattle performance and acidosis risks is needed.

[2] John McKinnon, Draft Review, May 2017

[3] National Beef Quality Audit 2010/11 http://www.beefresearch.ca/files/pdf/factsheets/nbqa_full_brochure_feb_2013.pdf, accessed on April 5, 2017

Monensin reduces meal size and increases meal frequency, helping stabilize intake and moderating pH fluctuations. Thus, monensin has become a valuable “bunk management” tool at the feedlot, allowing higher energy diets to be fed. Recent research has also explored alternative natural ingredients (e.g. calcium oxide[4]) that similarly alter feeding behavior. Other areas that influence acidosis such as grain processing, fibre levels and fibre chop length deserve further investigation as “bunk management” tools that minimize acidosis.

The ability to document feeding behavior and pH of individual animals, have seen scientists observing large variations between animals in both parameters. If we could identify which animals were susceptible to acidosis challenges, perhaps they could be managed separately enabling the majority to be fed more cost-effective diets.

The areas of bunk management that justify more research include: 1) the identification of ways to manage cattle aggression at the bunk (i.e. frequency, timing of delivery; ingredients that slow down eating rate, etc.); 2) study on the benefits and feasibility of multiple feed deliveries in commercial production system; and 3) research that links bunk management to Subclinical acidosis in feedlot cattle, feed processing and preparation, feed efficiency and production, and defining the impact of differences in feeding behaviour of individuals on bunk management and animal health.

Effective **ration management** in feedlots should ensure adequate supply of daily nutrient for the animal. It should also be economical, palatable and free of toxic substances. Guidelines on ration management and decision making tools have been developed by provincial governments. Research on liver abscesses (LA) control suggests that inclusion of physically effective roughage in the diet, in a sufficiently coarse form, and in sufficient quantity that allows development of a robust and persistent fiber mat within the rumen, appears to provide the most reliable control of LA. Future research should focus on means to maximize the benefits of roughage by altering the timing, level, and form of roughage included in finishing diets (Reinhardt and Hubbert, 2015).

Previous research investigated the impact of the inclusion of fat and oils in finishing diets on cattle performance. Conclusions differed across different types of oil supplements. Using these fat sources often do not fit into a least cost formulation diet unless they are off grade sources which are not widely available at a level that make them widely available as feedstuff. Economic research is needed to examine the cost and benefits of the inclusion of fat and oils supplements. Economic research on the cost and benefit of fat and oil supplements could be examined in future research.

Growth enhancing technology (GET) is among the many sophisticated tools used by feedlots and other producers to improve feed efficiency. Implants resulted in an increase of the ADG by 14.1% and improved feed to gain by 8.8%. Beta-agonists have a similar ADG effect as implants, but a larger impact on feed to gain. Implants have the largest cost savings effect or the technologies considered with 6.5% and over US$68/head higher cost if these technologies were eliminated. Ionophores and beta-agonists each reduce costs approximately US$12-13 per head or about 1.2%. The impact of beta-agonists is smaller than reported in their effect in ADG and feed to gain because they are used for a relative few days at the end of the feeding period.

Despite GET being used to increase feed efficiency, reduce natural resource use and improve cost effectiveness their use is questioned by the general public. Capper and Hayes (2012) project increased costs of U.S. beef produced without GET resulting in the effective implementation of an 8.2% tax on beef production, leading to reduced global trade and competitiveness. There is currently no Canadian estimate to demonstrate the potential impact of the loss GET; as well as the potential impact from their elimination

[4] Calcium oxide treatment has similar effects in reducing digestive upsets, but it does not have the same effects in bloat and cocci control, feed efficiency improvement. (Dr. John McKinnon, Draft Review, May 2017)

in terms of increased EU trade and consumer willingness to purchase. There is also a need for a national technology transfer program aimed at the public that promotes their safety, environmental, economic, production and societal benefits. Research that looks at the alternative products or management methods is also needed.

Parasite Control contributes to improved feed efficiency, by 3-4%. The potential costs of addition feed required due to the absence of parasite control is estimated at $25-40 million per year for the Canadian beef industry (using 2012-16 average barley price). While the beef industry has relied on the use of pour-on macrocylic lactone drugs (e.g. ivermectin) to control GIN parasites for the last 30 years, resistances to the macrocyclic lactones, as well as other anthelmintic drug classes, have emerged worldwide and now threaten sustainable parasite control (Gilleard, 2016). Obtaining information on the prevalence of drug resistance, developing optimal treatment options will be important research areas for the beef industry. In addition, investigating producer perceptions and developing policies to maximize the adoption of new technologies, as well as the comparison of cost-benefit of different parasite control strategies is also important.

Genetic improvement programs should include traits related to feed efficiency to reduce input costs, as 70% of beef production costs are feed related. Differences between animals in feed required per unit of metabolic body size, including those due to genetics or breeding value that can be changed via selection. The magnitude of these differences is relatively large enough to imply that reduction of 15 to 20% in maintenance costs would be achievable through long-term selection (Nielsen et al., 2013). The challenge is that feed efficiency is a genetically complex trait involving many genes and interactions, and it can be affected by many other factors; and currently there is little information on what most of the genes are or what they do. Unintended consequences through breeding and genetic selection is a concern as limited information is available on their impact on other traits such as quality grade, tenderness, fertility, and longevity.

DNA markers (e.g., single nucleotide polymorphism (SNP) and microsatellite) is a potential tool for genetic improvement in beef cattle and other species. An on-going research in Canada aims to use the 50K SNP chip to identify DNA markers associated with feed efficiency, to improve the reliability of DNA tests for feed efficiency. A multiyear project in the U.S. aims to develop selection tools and better understanding of feed efficiency in beef production. The program has developed a feed efficiency calculator that allows Bull or Heifer Developers to calculate the Raw Feed to Gain, Adjusted Feed to Gain, Residual Feed Efficiency, Residual Gain and Feed Efficiency Index on tested contemporary groups.

Further research is needed to have a greater understanding of rumen biology, and the interact of the feed efficiency with other traits. Research is also needed to assess and understand the genetic correlation between feed energy requirement for maintenance per unit size in a growing calf in a feedlot versus in a reproducing cow. Data on feed intake and utilization on heifers is lacking. Therefore, more study is needed to appropriately account for the associations of feed intake and other economically relevant traits in the mature cow. Technologies to efficiently measure feed intake for feedlot and grazing animals is also important. Research is also need in the selection for more forage efficient cows – cows that can consume large volumes of low cost forage, maintain condition, and have high reproductive efficiency.

Manure Management

Manure nutrient content and quantity produced is impacted by the feed ration and feed efficiency of the animal. Manure management is an increasing challenge facing the intensive livestock industry. It is important for livestock operators to use recommended management practices (RMP) to prevent environmental or agronomic problems from developing. From an environmental standpoint, it is advised that feedlot manure should be managed based on P nutrient content versus N content when developing a long-term manure management plan.

When feedlot manure is applied to meet the N requirements of a crop, P will be applied at approximately three to six times the rate of crop removal. To date, Manitoba is the only the province of has developed legislation to control maximum soil P levels in agricultural soils. The hesitation to recommend soil P limits was because many feedlot operations only have a land base large enough to dispose of the N in manure and balance N application with crop up take requirements. If soil test P limits were imposed, this would mean many feedlots would need to increase their land base by three to six times to balance the amount of P in manure produced with crop uptake and removal. This is a major issue and a great challenge for feedlot operators in western Canada.

Beef feedlot manure has received considerable research attention. Research projects on the impact of manure application on crop nutrient and its environmental impact, as well as the economic efficiency of different manure handling methods were conducted in Canada. Technology transfer information on manure management and computer programs have been developed by the Alberta, Saskatchewan, and Manitoba provincial departments of Agriculture, and are publicly available on their websites.

Suggested further research topics on manure management include: 1) Develop and test equipment and technologies that can economically apply manure at rates that meet annual crop P and N requirements and reduce loss of manure nutrients during application; 2) Further develop and assess environmentally effective beneficial management practices that producers can economically and practically implement; 3) Further examine maximum phosphorus limits for runoff from agricultural land and receiving streams and rivers; 4) The implementation of soil-test phosphorus limits may result in significant financial hardship to the intensive livestock industry, particularly the beef feedlot industry. Additional research and policy analyses are needed to develop alternative methods of managing excess manure from existing operations; 5) A new economic study to evaluate the cost of transporting fresh manure and composting manure based on current fuel, labor, trucking costs versus commercial fertilizer use would be beneficial; 6) Apply manure used variable rate technology to more effectively match and utilize nutrients in manure and in variable soils; 7) Methods to improve feed nitrogen utilization by cattle, and to decrease nitrogen excretion, and ways of reducing nitrogen losses from the pen and stockpiled manure are needed; 8) Studies on the role of manure in soil reclamation, particularly areas where significant organic matters has been lost; 9) Links to manures ability to promote carbon sequestration.

INTRODUCTION

In 2012, the Beef Cattle Research Council (BCRC) committed to completing an evaluation of the value of research funded in each priority area: Beef Quality & Food Safety, Forage & Grassland productivity, Animal Health & Welfare, Feed Grains & Feed Efficiency. The goal of these priority area reviews was to provide a cost:benefit analysis of research to identify research areas within each priority that were potentially under- or over-funded. This is intended to inform the next round of priority setting sessions by providing more in-depth background for the participants.

Why invest in feed grains and feed efficiency?

There has been much discussion globally about how agriculture will meet growing demand for animal protein in an environmentally acceptable manner. Exponential growth in global human population and a general increase in per capita consumption of animal products require technologies that will produce more animal protein while using fewer natural resources (i.e. feed, water), reducing negative environmental impacts such as emitting fewer greenhouse gases (GHGs). At the same time, the quality and safety of the final product should not be compromised (Strydom, 2016).

The National Beef Sustainability Assessment (CRSB, 2016) indicates that after enteric methane, feed production and manure are the next largest contributors to GHG emissions. Research around feed grain production and utilization can make a major contribution to environmental sustainability of the Canadian beef industry.

From a producer' perspective, improving the feed efficiency of a herd can mean big savings on production costs. A 5% improvement in feed efficiency could have an economic effect four times greater than a 5% improvement in average daily gain – this scenario assumes that faster gaining cattle will be sold sooner, rather than at a heavier weight; the potential of additional advantage of feeding more cattle each year is not factored into the calculation (Gibb and McAllister, 1999).

Improved feed efficiency is associated with both positive economic and environmental benefits[5]. A unit reduction in feed intake (kg as fed/day) is associated with an average increase of $13.23 in net returns and 33.46 tonnes reduction in emissions at the end of the feeding period (Boaitey et al. 2017). On a percent intake basis, this translates into a 2.3% increase in net returns for each percent improvement in efficiency. This is lower than the 4.3% increase in profits reported in Fox, Tedeschi and Guiroy (2001). It should be noted that the modelling the two studies were different.

While there have been significant improvements in feed efficiency over the years that have contributed to greater consistency in animal performance there are still gains to be made. Boaitey et al. (2017) reports feed efficiency scores ranging from a 4.02 kgs (as fed/day) below the control (these are the most efficient cattle) to 4.16 kgs (as fed/day) above the control (least efficient) on 5,600 cattle – implying there are significant gains to be made.

OVERARCHING OBJECTIVE for FEED GRAINS & FEED EFFICIENCY:

Improve feed efficiency through the identification and validation of economical methods of identifying seedstock with improved feed efficiency and the development of alternative feeding strategies. Feed efficiency involves both the feed (nutrient composition, processing, etc.) as well as the animal (ability to extract and use these nutrients).

[5] Producing the same amount of beef in 2011 required 29% less breeding stock, 27% fewer slaughter cattle and 24% less land, and produced 15% less greenhouse than in 1981. (Legesse et al. 2016)

In focusing on feed efficiency at the feedlot, there is a concern that selecting for heavier carcass weights drives selection for a larger mature cow herd that actually requires more, not less, resources to be maintained. It can also create an economic incentive at the feedlot to produce more yield grade 3 cattle that actually have less lean muscle yield than yield grade 1 cattle, offsetting the productivity gains industry thinks it has made. These unintended consequences can be large and always need to be kept in mind. Multiple productivity measures can be used to examine if the industry is actually moving forward or backwards on this topic. The environmental impact, the cost of maintaining a larger mature cow, or production gains/losses from carcass yield. The results are not always clear cut.

Environmental productivity focuses on those aspects which reduce greenhouse gas (GHG) emissions. From 1981 to 2011, the Canadian beef industry reduced GHG emissions by 15% per kg of beef produced. This was primarily done through improved reproductive efficiency, growth enhanced technologies, larger carcass weights and reduced days from birth to slaughter.

If we are at the point with reproductive efficiency where diminishing marginal returns are kicking in – that is for every additional dollar invested equals only one dollar of economic gain for the producer – then environmental productivity improvements over the next 30 years are going to have to come from somewhere else. *Or are they?*

In the United Kingdom (UK), a McDonald's study from 2008 to 2014 resulted in reduced emissions of 23% on farms being monitored. This carbon footprint represents a drop of 4.6% per year for those in the study against an industry benchmark of 0.94%. This implied that the beef industry could achieve the 11% voluntary reduction target set by the UK government by 2020 if farms can successfully apply the principles learned during the study.

Top tips for carbon reduction across all farm types:

1. Measure and monitor – if you can't measure it you can't manage it.
2. Benchmark – to know where you stand versus other producers and other types of farms.
3. Focus on daily live weight gain – to reduce days on farm and digestive emissions.
4. Use protocols to consistently improve animal health – to safeguard welfare, reduce mortality and boost performance.
5. Maximize homegrown forage – through improved grassland management and diet formulation.
6. Reduce calving interval – breeding for fertility in cow/calf herds, ensuring close heat management and optimum age at first calving.

All of these recommendations will lead to a continuation of the trends seen in the last 30 years with producers focusing on average daily gain improvements, heavier carcass weights, and reproductive efficiency.

What is a larger mature cow costing the beef industry?

Carcass weights have been increasing 7 pounds per year on average over the last 45 years. There is strong correlation between larger carcass weights and weaning and birth weights; which are made possible by a larger mature cow weight. If a cow consumes 2% of her body weight on average while we have successfully increased the number of pounds produced per cow are we doing it with the same resources of forage per pound? And therefore, have we not really moved the needle at all?

In 2015, Canadian beef production was 2.6 million pounds (carcass weight). The all cattle average carcass weight increased from 803 lbs in 2011 to 865 lbs in 2015. A 50 lb increase in average carcass weight would reduce the number of animal slaughter by 6%.

Assuming that a 6% increase in carcass weight is driven by a corresponding 6% increase in mature cow weight it will increase the amount of forage required at the cow/calf level. But remember that there are 6% fewer cows needed. This means the cow/calf producer is actually left indifferent from a cost perspective. It takes the same tonnes of forage to feed 6% fewer cows that are 6% larger. But this doesn't mean that industry is indifferent. Are larger carcass weights a null and void improvement? If the same tonnage of forage is used the natural resource base has not changed. However, 6% fewer cows is still 6% fewer cows emitting methane. There is still an environmental benefit.

Table 1. Cow weight impact on feed consumption of the herd

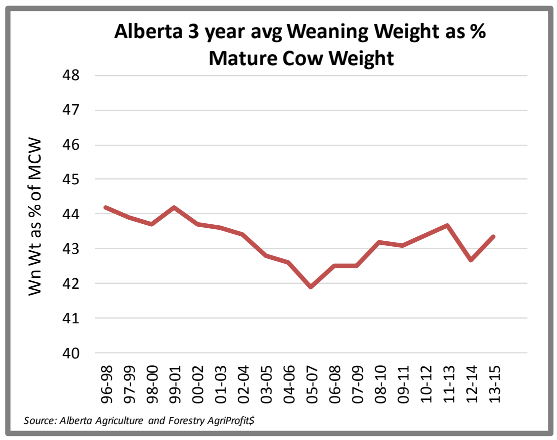
Cow weight	% weaned	weaning weight	All cattle avg carcass weights	Million head required	2% of body weight per day	Forage/ cow/year	Lbs of forage
1200	40%	480	800	3.32	24.0	8,760	29,113
1275	40%	510	850	3.13	25.5	9,308	29,113
1200	45%	540	900	2.95	24.0	8,760	25,878

The battle of the cow size where larger is always bad and smaller is always good does not necessarily hold true. Producers can choose the animal that best suits their environment and performs. It should be noted that not all cows have gotten larger over time, and there are genetic opportunities within the existing population.

Improve Weaning Weight to Cow Weight Ratio

To wean 45% of mature cow weight instead of 40%. To leave the mature cow weight unchanged and increase the pounds produced, ultimately resulting in less feed required.

According to Alberta Agriculture's AgriProfit$, the three-year average for weaning weight as a percentage of mature cow weight made a low in 2005-07 at 41.9% and has rebounded to 43.3% in 2013-15 but is still below the high of 44.2% made in the late 1990s. The low-cost producers tended to be higher than the average around 44-45%.



Weaning weight as a percentage of mature cow weight is an important productivity measure for cow/calf producers; particularly as it pertains to feed efficiency and mature cow size. But it excludes perhaps the dominant economically relevant trait which is reproductive performance.

Residual Feed Intake

The above calculations assume a cow eats a constant 2% of body weight. Residual Feed Intake (RFI) is the different between an animals actual feed consumption and the calculated prediction of how much an animal of its size would need to eat for maintenance. It should be noted that this approach assumes prediction in absolutely correct which is never the case.

RFI is moderately heritable and genetically unrelated to body weight and average daily gain. The benefits of improving RFI and the percentage of body weight the average cow in the herd eats is valuable to the cow/calf producer only if there are no adverse impacts on other productivity measures and can be adopted widely within the commercial herd.

Research[6] has shown that selection for low RFI (efficient cattle) will:

1. Have no effect on growth, carcass yield & quality grade
2. Reduce feed intake at equal weight and ADG
3. Improve feed to gain ratio by 10-15%
4. Reduce net energy of maintenance and reduce methane and manure production (reducing the carbon footprint of cattle)
5. Have little if any effect on age at puberty
6. Have no effect on calving pattern in first calf heifers
7. Have no negative effect on pregnancy, calving or weaning rate
8. Have little effect on bull fertility
9. Have a positive effect on body fatness or weight particularly during stressful periods
10. Will reduce feed costs
    - $0.07-0.10/hd/d feeders
    - $0.11-0.12/hd/d in cows

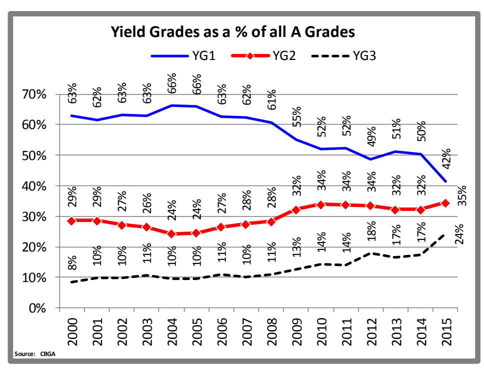
While RFI has been around since 1957 it has not been widely used because it is so difficult to get data (cattle must be fed separately and feed intake monitored). Research has shown that animals may re-rank (low, medium, high) for RFI depending on the type of diet (grain, forage), age and feeding system (drylot, winter grazing, summer pasture). Making this tool of limited ability to move the needle for the national industry.

In addition, there are questions about the relationship of RFI with reproductive efficiency in mature cows (Lancaster, 2012). Studies suggest that RFI measured in growing cattle and mature cows is genetically the same trait, but that expression of genetic potential may be altered due to physiological state of the animal. The reason for the low correlation between RFI of growing cattle with RFI of mature cows is most likely due to differences in nutrient metabolism. Nutrient metabolism in the mature cow is complex and can be prioritized for different functions, (i.e. lactation, fetus development, body reserves) as required, other than growth.

While it is unclear if there is a connection between low-RFI and fertility[7]; there is a clear connection between Body Condition Score (BCS) and reproductive performance. Given the large impact reproductive performance has on per unit cost of production - perhaps the most economically relevant trait then is “feed required to winter a cow while maintaining a BCS of 3”.

Carcass Yield implications on Beef Production Productivity Gains

Productivity improvements must occur throughout the supply chain. Producing the same tonnage of beef based on a carcass weight basis and a steady dressing percentage; can be offset by reduced yield performance. There has been a trend towards more yield grade 3 cattle since 2004. This additional fat is expensive to put on, requiring more feed and is an additional expense to trim off at the packing plant. This measure can be frequently lost or forgotten as most productivity measures are reported in carcass weight or live weight.



6 BCRC, Beef Cattle Research Council - Genetic Improvements in Feed Efficiency http://www.beefresearch.ca/research-topic.cfm/genetic-improvements-in-feed-efficiency-57?language=&print#rfi, accessed on June 12, 2017

7 Lancaster, P. 2012. Impact of Selection for Feed Efficiency on Cow-Calf Production. http://animal.ifas.ufl.edu/beef_extension/bcsc/2014/pdf/lancaster_final.pdf , accessed on April 18, 2017

Given the trend over the last decade, the question becomes have all the productivity gains been eliminated due to changes in yield performance? The below table shows Canadian Beef Grading agency data for yield grades on A grade cattle. Again, using the 2015 production number of 2.65 billion pounds carcass weight, the separable lean meat tonnage is estimated. The difference from reduced yields was 1% from 2004 to 2011 and 3% over the last decade from 2004 to 2015.

Table 2. Yield Grade impact on beef production

					Million lbs	Estimated Separable Lean Meat		
		2004	**2011**	**2015**	**Carcass weight**	**2004**	**2011**	**2015**
YG1	>=59%	66%	52%	42%	2,659	1,073.12	846.92	673.23
YG2	54-58%	24%	34%	35%	2,659	360.67	502.59	513.89
YG3	<=53%	10%	14%	24%	2,659	130.41	191.27	328.19
Separable lean meat:						1,564.19	1,540.78	1,515.31
Difference from 2004 peak yields:							-1%	-3%
Tonnage difference (million lbs) from 2004 peak:							(23.41)	(48.88)

This implies that productivity gains elsewhere must be larger than this to offset the losses from reduced yield performance. Industry needs to ensure that the price signal is there to create the incentive for production of YG1 cattle and not YG3 cattle.

When we look at efficiency there is no silver bullet, we need to consider the environmental, natural resource and economic implications of 1) How many animals must be maintained to produce the same tonnage of beef - reproductive efficiency, carcass weights, number of cattle marketed; and 2) feed efficiency – at every stage of production. Weaning weight as a percentage of mature cow weight, residual feed intake and body condition scores are important indicators for the cow efficiency.

Report Structure

This review consists of three main research areas: 1) Feed Grain productivity and utilization through breeding, processing and use of alternative feeds; 2) Feed efficiency as affected by bunk and ration management, use of growth enhancing technologies, parasite control, and animal genetics; 3) Manure management. Under each research area, different topics are reviewed to provide information on the background, current research, available tools, and future research opportunities.

FEED GRAINS

The profitability and health of the finishing sector relies in large part on the production of high quality and yielding feed grains, and animals that are highly efficient in converting feed mass into increased body mass. Research in feed grain is needed for the development of new feeds and alternative feeding strategies, improvement in feed supply and utilization.

FEED GRAIN BREEDING

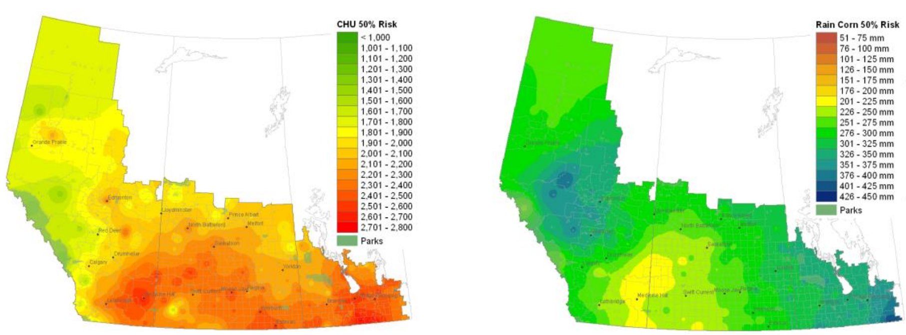
The goal of breeding programs for corn and barley are to improve yield and develop varieties that adapt to changing climate conditions for future production. The beef industry needs two different types of yield: (1) stronger and shorter stems to support higher grain yielding barley with reduced lodging; and (2) stems that maximize forage production for silage. The first goal is already being addressed by the barley industry, as they too are focused on grain yields. However, the second goal of higher forage yield is not. A third goal of annual forage breeding programs could be varieties that hold nutritional value for extended fall/winter grazing. See the Forage and Grassland Productivity Priority Area Review for more details.

What is value of the beef industry investing in barley?

Corn yields are higher, improving faster, supported by private industry investment, and their geographic range is expanding into western Canada. Corn has significantly higher yields than cereals (i.e. barley) if environmental conditions are favorable and even with higher input costs tend to have a lower per unit cost of production contributing to a lower land use and cost of gain for cattle. As corn varieties have been developed that have a shorter growing season and require less heat units, the development in corn breeding helps diversifying the feed grain sources for the cattle industry in the face of climate change. The question becomes how do these feed sources co-exist with each other in Western provinces.

BARLEY VS. CORN

Barley is the primary feed grain energy source in western Canada, while beef production in eastern Canada is based on corn. Traditionally, corn's high requirement for heat and moisture made it unsuitable for climate in western Canada. A number of new corn varieties that require fewer than 2300 CHUs to reach maturity have become available (e.g. P7005AMTM-2000 CHUs; P7202AMTM-2050 CHUs; P7211HR-2050 CHUs[8]. This makes corn production possible in some regions in southern Alberta, mid-west Saskatchewan, southern Manitoba where the average CHUs meet the requirement.



Source: Nadler, A. J. (2007). An agroclimatic risk assessment of crop production on the Canadian Prairies (Doctoral dissertation, University of Manitoba)

[8] Source: DuPont, Pioneer Seed Guide 2017 file:///S:/CRS/BCRC/Literature/Feed%20Grain%20-%20Corn/pioneer-seed-guide_2017-lr.pdf , accessed on April 5, 2017

Corn crops typically need 500 mm of water per growing season. The rainfall is generally below this in western Canada where adequate CHUs are available. Therefore, irrigation is important for the currently available grain corn varieties.

There have been studies looking for drought tolerant varieties suited for western Canada. However, balancing growth, yield and drought tolerance is a challenge. As shown in Table 3 and 4, the varieties with both low CHU requirement and high drought tolerance (e.g. P7211HR – 2050 CHUs, Drought Tolerance rating 8[9]), typically have lower yields offsetting some of the benefit. According to Alberta Agriculture, there are currently drought tolerant varieties available in the western United States; however, these varieties have CHU requirements too high for the Canadian Prairies to support their production. These traits will likely be making their way into earlier maturing varieties, with some drought tolerant traits already being tested. This means that corn acres could expand beyond irrigated acres and migrate into dry land production, but the timeline on such a shift is unknown at this point. Historically in other regions, as yields consistently reach 110 bushels per acre, the adoption rate of corn increases more rapidly (Alberta Agriculture, 2014a).

Table 3 Alberta Corn Committee Grain Performance List

2016 Alberta Corn Committee Grain Performance List†								
Company	Hybrid	CHU Rating‡	Location Years	Yield (bu/ac)	% of Pooled Mean	% Moisture	TWT (lb/bu)	Anthesis
Pioneer	P7005AM	2000	8	102.0	88	18.1	58.2	22-Jul-16
Pioneer	P7211HR	2050	8	116.5	97	19.9	56.4	22-Jul-16
Pioneer	P7332R	2050	12	113.6	98	21.5	54.9	27-Jul-16
Elite	E46J77 R	2150	8	123.0	105	21.7	58.6	24-Jul-16
Dekalb	DKC23-17RIB	2075	8	112.9	89	22.3	57.7	22-Jul-16
Elite	E47A12 R	2200	12	113.5	110	22.5	54.2	31-Jul-16
Elite	E49A12 R	2325	12	112.1	107	23.0	53.9	31-Jul-16
Elite	E44A02 R	2150	12	112.9	102	23.8	55.5	26-Jul-16
Thunder Seed	TH4578	2100	8	122.5	105	23.9	54.9	27-Jul-16
Dow Seeds	4093	2300	16	110.5	86	24.3	55.3	31-Jul-16
Thunder Seed	TH7578VT2P	2225	8	124.5	104	24.4	55.0	29-Jul-16
Pioneer	P7632AM	2225	12	119.1	103	24.4	53.7	29-Jul-16
Thunder Seed	TH7574VT2P	2100	8	119.6	103	24.8	57.1	24-Jul-16
Thunder Seed	TH7677VT2P	2200	8	125.2	102	24.8	55.1	29-Jul-16
Dow Seeds	DS80A27	2300	8	122.9	103	25.6	51.6	29-Jul-16
Pride	A4415G2 RIB	2200	8	111.0	90	26.5	57.1	24-Jul-16
† Based on results up to and including 2016. Hybrid must have a minimum of 5 station years of testing over two calendar years at the four core sites to be reported in this table. The four core sites are Lethbridge, Vauxhall, Bow Island, and Brooks.								
‡ CHU Rating provided by Company								

Source: Alberta corn Committee http://www.albertacorn.com/pdf_16/grain_performance_list_2016.pdf

Table 4. 2016 Albert Corn Committee Silage Hybrid Performance List

[9] 9=outstanding, 1=poor. Information and scores are assigned by pioneer research managers. Scores are based on period-of-years testing through 2014 harvest. Source: https://ca.pioneer.com/west/en/products/corn/

2016 Alberta Corn Committee Silage Hybrid Performance List†							
Company	Hybrid	CHU Rating‡	Location Years	Yield Tons/Ac (Dry)	% of Pooled Mean	Whole Plant Moisture %	Average Anthesis
Elite	Fusion RR	2200	34	7.5	98	59.5	02-Aug-16
Pride Seeds	A4177G3 RIB	2175	8	6.5	94	60.0	24-Jul-16
Greenfield Genetics	14T GTCBLL	2300	16	7.9	111	60.8	03-Aug-16
Dow Seeds	4093	2300	16	7.0	90	61.0	31-Jul-16
Pickseed	PS 2348VT2P RIB	2275	12	7.2	95	61.5	29-Jul-16
Maizex	MZ 1633DBR	2300	12	7.4	103	62.0	31-Jul-16
Greenfield Genetics	17X GT	2350	16	7.9	113	62.0	04-Aug-16
Elite	E47A17 R	2200	12	7.0	95	62.3	01-Aug-16
Thunder Seed	TH7578VT2P	2225	8	7.1	102	62.4	28-Jul-16
Pickseed	PS 2210VT2P RIB	2175	8	7.5	107	62.5	28-Jul-16
Pride Seeds	A4705HMRR	2325	33	7.3	99	62.7	03-Aug-16
Maizex	LF 730CBR	2300	8	7.4	99	63.0	29-Jul-16
Elite	E49A12 R	2325	12	7.1	90	63.1	31-Jul-16
Thunder Seed	TH4126RR	2250	8	7.5	100	63.2	28-Jul-16
Elite	YUKON R	2150	12	7.3	105	63.3	30-Jul-16
Pickseed	PS 2520VTP RIB	2400	8	7.6	109	63.6	31-Jul-16
Dow Seeds	DS80A27	2300	8	7.1	95	63.8	29-Jul-16
Thunder Seed	TH7677VT2P	2200	8	7.1	98	63.8	29-Jul-16
Pride Seeds	A5433G3 RIB	2500	12	7.8	106	64.2	02-Aug-16
Dow Seeds	X14008GH	2450	8	7.3	99	65.3	01-Aug-16
Elite	Venza R	2500	20	7.8	103	66.2	05-Aug-16
Pride Seeds	AS1047RR EDF	2400	16	7.8	106	66.6	02-Aug-16
Elite	E57L62 R	2650	12	7.9	98	67.7	03-Aug-16
Dow Seeds	TMF8106	2425	8	7.5	93	68.6	02-Aug-16
Dow Seeds	F2F298	2550	8	6.7	93	68.7	31-Jul-16

† Based on results up to and including 2016. Hybrid must have a minimum of 5 station years of testing over two calendar years at the four core sites to be reported in this table. The four core sites are Lethbridge, Vauxhall, Bow Island, and Brooks. For information on Lacombe's and long term performance results please refer to the corresponding table.

‡ CHU Rating provided by Company

Source: Alberta Corn Committee http://www.albertacorn.com/acc_hybrid_2016.html

Economics

Studies have shed light on the economic viability of growing corn in western Canada. The results show that despite higher input costs, grain corn has higher yield potential and thus higher returns, which makes it an economically competitive crop amongst the options to producers.

The Agriprofit$[10] data by Alberta Agriculture provided estimated cost and return for grain corn and other major crops in the irrigated soil zone. The 2013 data shows that the direct expenses on grain corn production is 58% higher than feed barley. Hence, while grain corn yield is 18% higher and resulting in 40% more revenue; the averaged margin for grain corn was $91.39/cwt per acre, 15% lower than feed barley.

Studies on grazing corn have also show that the new corn hybrids may be suitable alternatives for winter grazing strategies in Western Canada. Lardner et al. (2012) evaluated corn crops for grazing cattle and winter feed costs in western Canada. Experiments were done on five corn varieties during 2011 and 2012. Total crop production expenses are estimated between $207.60 to $226.36/acre. Grazing costs averaged $0.70 to $1.40/cow/day. Total daily feeding cost averaged over several years were $0.78 per cow per day for swath grazing triticale, $1.05 for grazing corn, $1.24 for swath grazing barley and $1.98 for a traditional total mixed ration of silage, straw and limited grain.

[10] Alberta Agriculture. The Potential for Grain Corn in Alberta http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/bus15031#future, accessed on January 27, 2017

An on-going research project led by Dr. Karen Beauchemin[11] is looking to obtain basic information on how genotype, growing location, and year influence corn silage yield, chemical composition, and nutritive value (in vitro digestibility). This research will provide the beef industry with needed information about the economic potential of incorporating high energy corn silage into feedlot rations.

In terms for tech transfer, decision making tools that can estimate the potential cost and return of feed grain or various forages, and compare relative nutritive values of different feeding sources could be useful for producers. An example is the Silage Production Cost Guideline[12], which compare production costs of barley, corn, and alfalfa-grass silage. As corn is a relatively new crop in western Canada, a number of existing decision making tools do not have corn as an option in the database. A calculator that compares projected cost and return of corn and other crop choices, considering production costs, prices, yields and nutritive value, could help producers in making production decision.

Nutrition

Gibb and McAllister (2003) compared corn and barley in feedlot diets. Corn is estimated to be 5-10% higher in energy than barley. However, it is lower in protein than barley and protein supplementation will be needed. Considering the differences in protein and the cost to supplement it, corn carries approximately 98% of the value that barley does. The authors also pointed out that corn needs to be steam flaked or fermented (stored high moisture) to capitalize on its high energy level, which is something that most Alberta feedlots are not set up to do (Alberta Agriculture, 2014a).

Table 5. Average Nutrient Composition of Grains, Dry Matter Basis.

Grain	Crude Protein %	Starch %	DE[a] Mcal/kg	ADF[b] %	Ruminal Starch Digestion % Total Starch[c]
Corn	10.3	75.7	4.1	3	65
Barley	12.7	64.3	3.7	7	87
Wheat	15.9	70.3	3.9	8	89
Rye	11.8	65.0	3.7	8	90
Triticale	15.7	67.0	3.7	8	90
Oats	11.6	58.1	3.4	16	92

[a] Digestible Energy [b] Acid Detergent Fibre [c] All grains were steam rolled, except corn which was cracked
Source: Alberta Agriculture http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/beef11489

Regarding corn forage, Lardner et al. (2017) compared three new low heat unit corn hybrids to barley for forage yield, nutrient profile, and total nutrient production. The study demonstrated that new low heat unit forage corn is comparable to conventional barley forage in major nutrients content (excluding Crude Protein) and availability to animals in major soil zone. These new cool-season corn hybrids can produce high quality forage to meet the nutrient requirement of grazing beef cow in mid-and late-stage pregnancy.

Corn Growing Area and Challenge in Adoption

The recent development and release of low heat unit variety has change the potential of corn use in cattle production in Western Canada. According to Statistics Canada, in the prairie provinces corn for grain seeded area totaled 370,000 acres in 2016, up 76% from 210,000 acres in 2007; while yield was up 39% from 101 bu/acre to 139 bu/acre. Fodder corn seeded area totaled 250,000 acres, up 61% from 2007. Corn for grain production was up 139% from 20 million bushels to 49 million bushel, and fodder corn production was up 95% from 2 million ton to 3.9 million ton. It should be noted that only a portion of corn production is used for as feed, while a significant portion also goes into food and industry use.

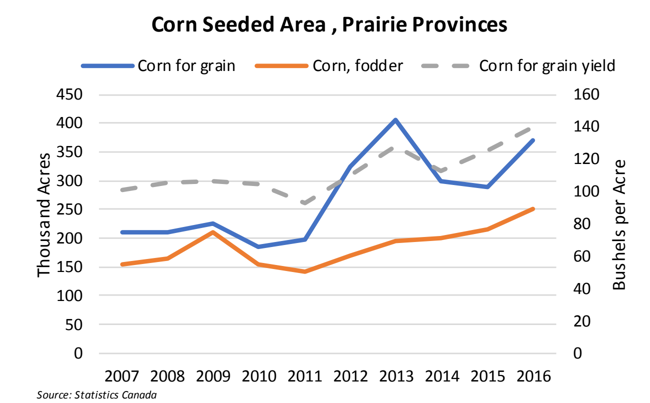
[11] Research Project, Evaluating Corn Silage, http://www.beefresearch.ca/fact-sheets/evaluating-corn-silage.pdf , accessed on April 5, 2017

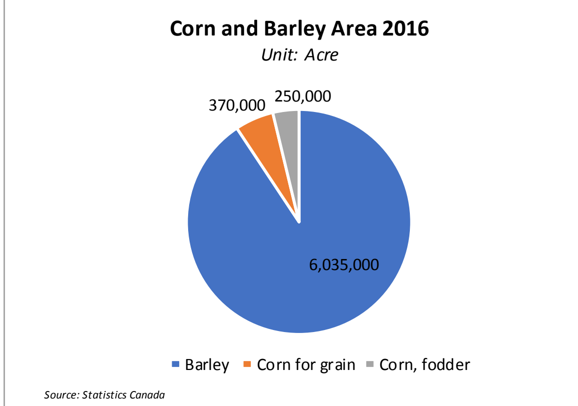
[12] Manitoba Silage Production Cost Guideline https://www.gov.mb.ca/agriculture/business-and-economics/financial-management/pubs/cop_forage_cerealsilage.pdf, accessed on February 6, 2017

According to Agriculture and Agri-food Canada, feed, waste and dockage accounts for 58% of Canada's domestic use of corn, while the other 40% is food and industry use.

Provincially, from 2007 to 2016, corn for grain seeded area was up 150% from 10,000 acres to 25,000 acres in Alberta, and up 73% from 200,000 acres to 345,000 in Manitoba. During the same period, fodder corn seeded area was up 38% from 80,000 acres to 110,000 acres in Alberta, up 20% from 75,000 acres to 90,000 acres in Manitoba, and up 233% from 15,000 acres[13] to 50,000 acres in Saskatchewan.

In comparison, barley area has been decreasing. From 2007 to 2016, total barley seeded area in prairie provinces was down 41% from 10 million acres to 6 million acres. Production was down 18% from 467 million bushels to 382 million bushels, with yield average yield up 46% from 51 bu/acre to 74 bu/acre.





Despite the rapid expansion in corn seeded area in the last ten years, corn area remains significantly smaller than barley. The area in corn for grain and corn for fodder accounted for less than 1% of the total farm land in Western Canada in 2016. Barley seeded area was 16 times of the area of corn for grain and 24 time of the area of the fodder corn. Barley, as well as wheat, remain the key feed grain source for cattle and beef production in western Canada.

In addition to CHU and moisture restrictions corn in the prairies, other key challenges to the adoption of corn include high input cost, labour shortage and processing capacity. To grow corn, producers will likely need to make a considerable investment in new equipment such as corn seeders, corn headers and drying equipment. Due to the larger yield of corn compare to some other crops, more labour will be required to move that larger volume of grain. Agronomic knowledge is another possible hurdle for corn adoption. This crop is relatively new to the Canadian Prairies, and so producers face a lack of knowledge and experience growing it, which could slow down the rate of adoption (Alberta Agriculture). Processing is also generally needed to capitalize on higher energy values (by steam flaking or fermenting), which is something that most Alberta feedlots are not set up to do. Alberta feeding operations must overcome some of these barriers before widespread adoption of corn will be seen (Alberta Agriculture).

The Importance of Barley

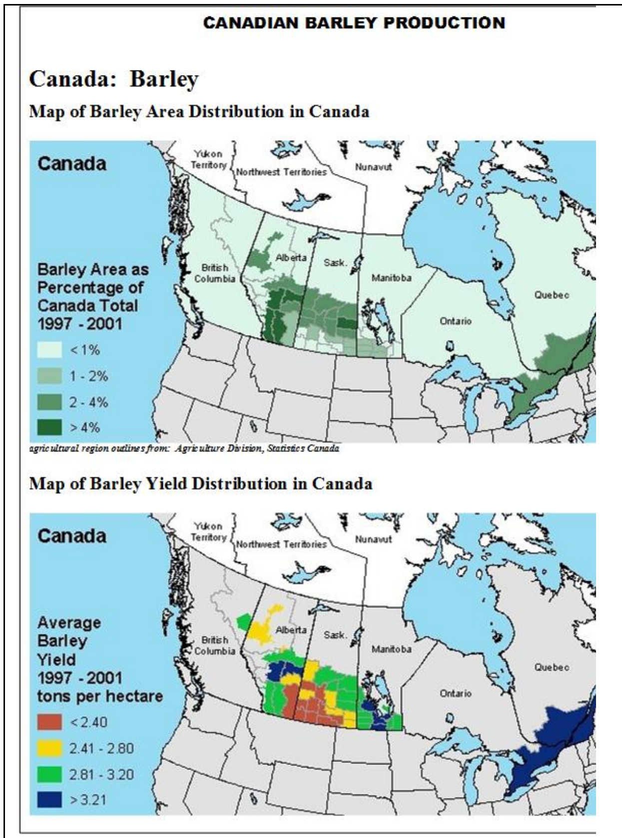
Alberta Agriculture (2014a) estimated that the potential corn consumption of Alberta's livestock industry is about 3.6 million tonnes (142 million bushels). The feedlot industry accounted for about 60% of the total at 2.2 million tonnes (86 million bushels). Given the long-term average corn yield at 114 bu/acre, approximately 1.2 million acres of corn production would be required to supply this quantity of corn to the livestock industry, and 750,000 acres would be required for the feedlot industry. For the 2016 crop

[13] Seeded area in 2008. 2007 data is unavailable.

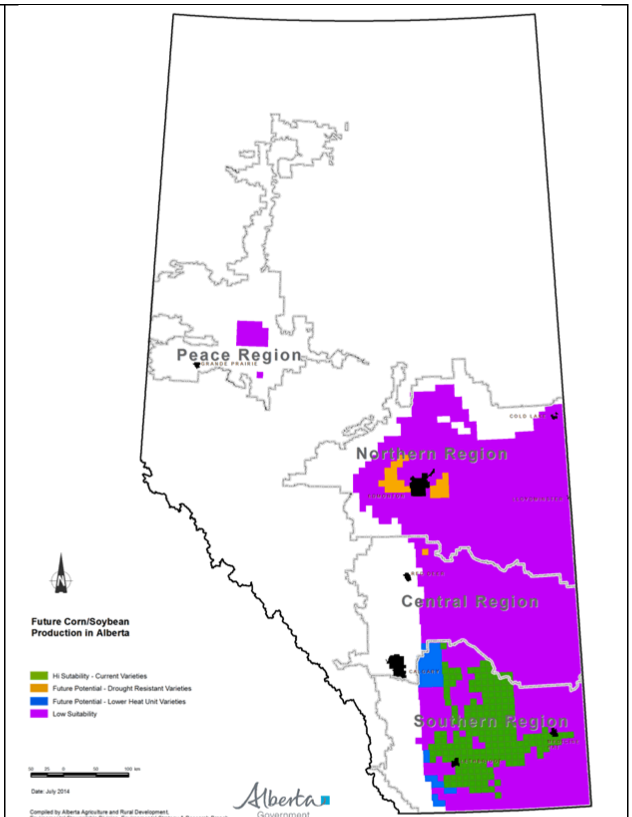
year, there were 25,000 acres of corn planted, which is significantly smaller than what is required for the feedlot industry.

The gap between the amount corn currently produced and the feed grain demand from the livestock sectors indicates the huge potential for corn production; but on the other hand, it means local feed grain demand remains heavily reliant on barley production.

As shown in the map below on the right, the green areas are already highly suitable to corn production, having adequate heat units and irrigation available to grow current varieties. The blue and yellow areas could see corn production in the future when lower heat unit or drought resistant varieties are available. The large purple area is marked as low suitability, would have sufficient heat units for existing or new expected varieties, but in most cases would require supplemental water to produce a crop (Alberta Agriculture, 2014a).



Source: Prairie Green Renewable Energe Inc
http://pgre.ca/feedstock/barley/



Source: Alberta Agriculture
http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/bus15031#eco

Comparing the corn potential map with the barley distribution map on the left, a large area that is not suitable for current corn varieties but is for barley production include a large part of the purple area and the peace region in northern Alberta. This area is currently a major barley producing region. Compared to corn's requirement for heat and moisture, barley does better in areas with moderate sunlight and moderate temperatures. This means there are some parts of the country where barley will always outperform corn (Bergen, 2014).

Barley is a relatively small crop in North America. It is self-pollinated, making hybrid development much more difficult and costly. Barley yields increase so slowly that it is difficult for growers to justify the cost of purchasing new seed every year. Saved seed is economical and legal, but the shortage of royalties means that there is little commercial incentive for private companies to get involved in barley breeding (Bergen, 2014).

Current feed barley research projects funded by the crop and cattle producer organizations, provincial and federal govenment (e.g. Western Grains Research Foundation, Alberta Barley Commission, Alberta Beef Producers, BCRC, etc.) cover research areas such as yield, disease resistance, feed quality, barley forage variety selection for enhanced feed efficiency, reduced manure production and lower costs of gain.

As pointed out Field Crop Development Centre 2016 Research Report, there is a lack of crop-based production “systems” scientists with background to work on topics that will have an economic impact on the beef industry.

In the next 10 to 20 years corn is likely to be the most significant change in cattle feeding coming in western Canada as varieties continue to be improved through private breeding companies. The questions we need to answer is how do these two feed grains and forage sources co-exist with each other, quite likely in the same operation. There is research opportunity in exploring if there is completive advantages to feeding blends of corn and barley, and in more extensive processing of barley and to some extent wheat.[14]

WHEAT

Wheat is also a primary feed grain in Western Canada. In eastern Canada, however, wheat is often more expensive, thereby restricting its use in rations (Ontario Agriculture, 2003). Feed-grade wheat that is of lower quality and thus unsuitable for milling, can be fed to domestic animals. From an economic prospective, wheat can be used to replace a part of the grain ration when wheat prices are competitive with other feed grains.

Nutrient Content and Feeding Recommendations

Wheat has an energy value similar to corn and is low in fiber and higher in starch content. It is higher in protein than other common feed grain such as corn, barley and oats (Lardy and Dhuyvetter, 2016). With low fiber levels and a rapid rate of starch digestion, wheat should be fed to cattle with caution to avoid digestive upsets. It is recommended that in moderate to high-grain rations (50 percent or more concentrate), wheat should be fed in combination with more slowly fermented feed grains and limited to 40 percent of the total diet to prevent or reduce the risk of digestive upsets (Lardy and Dhuyvetter, 2016).

Wiese et al. 2017 measured reticuloruminal pH in cattle in a commercial feedlot setting to determine the incidence and extent of low reticuloruminal pH for steers and heifers as they transition to a high-concentrate finishing diet (9.5% corn silage, 80% wheat grain, 10% DDGS, and mineral and vitamin premix). The results suggest that there is high risk but low extent for cattle to experience low reticuloruminal pH during a gradual dietary transition phase. This indicates that cattle can be successfully transitioned to wheat-based finishing diet with PH effects of a relatively mild severity, provided it’s done carefully and slowly (Bergen, 2017). Also, as cattle vary considerably in their ability to cope with high grain diets, more research would be needed to determine what are the drivers for these differences (Bergen, 2017).

[14] John McKinnon, Draft Review, May 2017

Sprout-damage and Ergot

Studies shows that sprouted grains are similar in feeding value to undamaged grain when fed to cattle. However, mold and fungal infestations are more likely with sprouted grain. Care must be taken to avoid feeding moldy wheat to livestock to prevent mycotoxin poisoning (Boyles, 2015).

Ergot develops when a fungus called Claviceps purpurea infects susceptible grass and grain plants during flowering. Rye is most susceptible annual crop, followed by triticale, then wheat (Bergan, 2014). Consumption of ergot-contaminated grains can have negative effects on feed intake, growth, and reproduction, but factors such as livestock species, age, and the presence of other stressors such as heat or cold can influence the extent of negative health outcomes (Schumann et al. 2009).

Coufal-Majewski et al. (2016) reviewed the impacts of cereal ergot in food animal production. The study pointed out that although legislation establishes tolerances for ergot alkaloids or ergot bodies in livestock feed, in most cases these concentrations have not been established through toxicological studies with livestock. A science basis recommendations for regulations and recommendations for ergot alkaloid level in animal feed exist is generally lacking. With grain contamination by ergot increasing annually and globally, effective new technologies are required to either reduce the occurrence of the ergot in grains or reduce the toxicity of alkaloids for livestock.

Triticale

Triticale is a hybrid of wheat and rye. As a rule, triticale combines the yield potential and grain quality of wheat with the disease and environmental tolerance (including soil conditions) of rye. It is grown mostly for forage or fodder.

McCartney and Vaage (1993) compared yield and feeding value of barley, oat and triticale silages, and concluded that barley, oat and triticale produced suitable silages for cattle feeding on the basis of yield and chemical composition. However, based on animal performance, triticale silage was less acceptable than either barley or oat silage. There appeared to be no animal performance advantage in producing triticale silage for cattle feed as compared with barley or oat silage. However, it does provide agronomic advantages in spreading out the silage season and providing a crop rotation for feedlot acres dedicated to silage production.

In recent years, breeding program has developed new triticale varieties that are cold tolerant, high yielding, earlier maturing and shorter for better grain production, and with improved digestibility and smaller awns for forage uses (Lovell, 2016).

ALTERNATIVE FEED GRAINS

Alternative feed grains like Dried Distiller Grains (DDGs) need to be addressed as they become available in the marketplace. When weathered crops become feed grade, there are questions on: when are they no longer even useful for feed; how to handle/store product to ensure quality and consistent feed for cattle; proportion of the diet it can represent before negatively impacting animal health and performance. Currently the most prevalent issue has been quality issues with feed grains particularly mycotoxins (i.e. ergot, fusarium).

Fusarium Head Blight (FHB) is a fungal disease of various grasses. It is found most often in wheat, but can be in barley, oats, rye and some forage grasses. From 2014 through 2016, incidence throughout western Canada has spread and become prevalent, particularly in wheat. Resulting in large supplies of feed wheat becoming available to the beef industry.

Under certain environmental conditions the fusarium mold may produce a mycotoxin. This mycotoxin is called deoxynivalenol (DON), and it is considered a mild toxin, compared to other toxins that can form in grains and forages. Livestock may encounter reduced feed intake, decrease in performance and reduced immune function as only symptoms of DON toxicity[15]. Mycotoxins can act in a synergistic manner, and the presence of other mycotoxins may cause an animal to show toxicity symptoms at lower than expected dietary levels of DON.

Different livestock species respond differently to DON. In ruminants, DON has been shown to be poorly absorbed, extensively metabolized and rapidly cleared from tissues and fluids. Agriculture and Agri-Food Canada's (AAFC) guideline is 5 ppm for growing beef cattle. The guidelines for DON levels in feed is based on a 100 per cent dry matter basis and refer to the complete ration, including the forage component. For example, grain with a DON level of 15 parts per million (ppm) could meet the guideline for growing cattle if it makes up one-third of the animal's total dry matter intake. The remaining two-thirds of the ration could be forage. Growing-finishing cattle can tolerate much higher levels of DON in their diet without going off-feed. In a University of Minnesota feeding trial (1993-94) steers were fed rations containing up to 18 ppm DON through the finishing phase with no effect on gain, feed intake or feed efficiency. An NDSU trial (1993-94) fed up to 9 ppm DON during the growing phase and up to 12 ppm during the finishing phase with no effects on performance.

North Dakota State University fed heifers rations containing 10 ppm DON, on a dry matter basis, during mid and late gestation. No differences in feed intake, gain, calving rate or calf birth weights were observed. It appears, at the levels tested, DON has no effect on reproductive performance.

Although there is literature suggesting that DON could be relatively safe to feed to cattle, it should be noted that the presence of DON can be a warning sign that other mycotoxins are also present. And there are still lots of unknowns in the combined effect of DON and other mycotoxins such as T-2 and HT-2 toxins.

Robens and Cardwell (2003) reported that contamination of feed with mycotoxins costs producers $5 billion in the U.S. and Canada alone. Mycotoxin contamination is very difficult to trace and measure, and the usual practice of using anti-mycotoxin agents as a preventative measure is a costly approach that has no guarantee of success. There is research needed on the crop side to determine how to break the disease cycle within the fields, as well as the research on the factors that induce mycotoxin production as you can have mold with mycotoxins and mold without mycotoxins. But there also needs to be timely and responsive research on the livestock side on how to best utilize these feed sources. This makes it difficult for BCRC with a five-year funding horizon to respond in a timely manner to these types of opportunities that come available to beef producers. The main role for BCRC is technology transfer of existing information and resources; and take an active role in facilitating research on alternative feed resources. on the issues as they come up in the marketplace.

GRAIN PROCESSING

Grain costs represent a significant proportion of a feedlot's (finishing & backgrounding) day to day cost. Therefore, it is essential for cattle feeders to optimize the use of grain to remain competitive. Digestibility of grains like corn, barley and oats is improved when grains are processed. By cracking the outer shell of the grain, rumen microbes are better able to utilize grain starch and minerals. Processing also allows grain to be mixed with supplements, and affects palatability and passage rates. However, processing grains too

[15] Manitoba Agriculture, http://gov.mb.ca/agriculture/livestock/production/beef/feeding-fusarium-contaminated-grain-to-livestock.html , accessed on April 5, 2017

finely leads to acidosis. Finding the ideal method and level of processing contributes to improved feed efficiency (BCRC, 2016).

BARLEY PROCESSING

Barley grain is the major energy source used in the diets of beef cattle in western Canada. Digestibility of barley grain by cattle is affected by factors such as the extent of grain processing, processing method, starch level.

Processing Index

The extent of processing can be quantified as Processing Index (PI). PI is calculated as the bushel weight of the barley after processing expressed as a percentage of the bushel weight before processing. This index reflects the fact that the more extensively barley is processed (i.e., the higher the degree of processing), the finer the particle, hence the lower the PI.

PI is an easy procedure to apply at the feedlot since most grain processing facilities have equipment for measuring the weight of a known volume of grain. While a number of studies have shown significant relationship between PI and grain digestion and animal performance (Yang et al., 2000; Beauchemin et al., 2001; Koenig et al., 2003); more recent studies suggested that using only PI as a measurement for extensity of grain processing may not be reliable if the grain kernels are highly variable in size (Yang et al. 2015) as it is likely unable to differentiate the feed value of processed barley that varies in volume weight or kernel uniformity (Yang et al., 2013).

Processing Methods

Physical processing techniques such as grinding or rolling increase digestibility of grain (Hironaka et al., 1992). While dry rolling is widely used in barley processing by the western Canadian feedlots, a recent by Zhao et al. (2016) evaluate the effect of starch content and processing method of barley grain on in situ ruminal dry matter (DM) and starch digestion kinetics, and reported that grinding versus dry-rolling increased the extent and rate of disappearance of dry matter and starch[16]. These results indicated that manipulating starch content of barley grain or PM could effectively alter ruminal and intestinal digestion of barley grain.

The quality of processed barley and its particle size distribution is particularly affected by kernel distribution. The size of barley kernels varies considerably among barley varieties and harvesting year (McAllister et al., 2011). Commercially, feed barley is often marketed as a blend from different varieties or locations during handling and transport (Zhao et al. 2016); light weight barley is commonly blended with heavier weight barley to create a mid-weight barley that is more acceptable to the market (Zhao et al., 2014). This results in wide variations in kernel size even within a single barley load, making it difficult to achieve optimal processing with a single roller setting when the barley is dry-rolled prior to feeding (Yang et al., 2013 and Zhao et al., 2014).

As kernel uniformity makes it difficult to obtain optimal utilization of barley grain through dry rolling, screening of blended barley into more uniform fractions and precision processing of each fraction could increase intake of digestible nutrients for feedlot cattle (Yang et al., 2013). Technology transfer is an important aspect as producer needs to agree to put in the equipment and slow down and be more precise in their processing methods to make this work. More time requires more labour which is a challenge for the industry.

[16] It should be noted that the factors that make grinding undesirable in vivo are not measured in vitro. (Dr. Karen Beauchemin, draft review, May 2017)

Another possible technology transfer approach is a grid pricing system that provides price signal for suppliers. In addition to buying on a bushel weight basis, feedlots pay premiums or discounts based on a plumpness index. For example, 90% plus plump gets a premium, 85% or less gets graded levels of discount.[17]

A couple of feedlots in western Canada have installed steam-flakers for barley. Steam flaking was not a commonly used processing method for barley in western Canada as it associated with higher costs. However, if the improvement in animal performance or feed efficiency more than offset the additional costs, steam flaking could be an economical option. The economics of steam-flaking barley and how cattle respond to steam flaked barley has not been well understood. Grimson et al. (1987) found no differences in average daily gain or feed efficiency when comparing dry rolling to steam flaking in barley based finishing diets. But cattle fed steam flaked barley tended to have higher dry matter intakes and had lower incidence of liver abscesses compared to cattle fed dry rolled barley. Engstrom et al. (1992) found no advantage for steam flaking over dry rolling in a trial conducted with 750 lbs beef steers. Average daily gain, feed efficiency, and dry matter intake were not significantly different for dry rolled versus steam flaked barley. More research is needed in this area to better understand the economics of steam flaking barley.

Starch Content

Researchers also examined the relationship between starch and fibre contents in feed and cattle performance. Effective digestibility of DM and starch in the rumen and in vitro digestibility of starch and DM in the intestine were increased by the starch level (Zhao et al., 2016).

Silage Proportion and Chop Length

North American feedlot finishing diets typically contain a proportion of roughage to minimize digestive disorders (60-100g/kg often used in western Canadian diets) (Koenig and Beauchemin, 2011). Research have shown that increasing the silage proportion in diet may reduce the risk of acidosis, but feed conversion efficiency is lowered. (The optimum level of roughage will be discussed in the Feed Ration section.)

In western Canada, barley forage is typically chopped to a theoretical chop length (TCL) of approximately 1.0 cm (short chop) to optimize ensiling (Addah et al., 2012). Recent research by Addah et al. (2015) investigated the effect of barley silage chop length and inoculation on growth performance, feeding behaviour, and ruminal acidosis in finishing feedlot steers. The study concluded that incorporation of longer chopped silage (2.0 cm) into a finishing diet increased dry matter intake, with responses of ruminal pH to inoculation differing between short chop and long chop silage. Increasing the TCL of barley silage from 1.0 to 2.0 cm may have no additional benefits to finishing feedlot operators as it did not improve rumen function or the growth performance of feedlot steers.

Near-Infrared Spectroscopy

Near-infrared spectroscopy (NIRS) is a rapid analytical tool that can predict fecal composition and diet digestibility without requiring samples of the diet or estimates of intake if appropriate calibrations are developed (Jancewicz et al., 2016). Changes in grain processing and in the forage to concentrate ratio resulted in measurable changes in fecal composition and nutrient digestibility that were predictable using NIRS.

[17] John McKinnon, Draft Review, May 2017

Table 6. The Value of Grain Processing

Grain Processing Index (PI)	% Starch in Feces	Kg grain loss/hd	$ loss/hd/day	$ loss/hd/120d	$saving/hd/120d
Barley PI85	15.85	0.64	0.12	14.20	
Barley PI75	10.84	0.44	0.08	9.70	4.50
Wheat PI85	23.44	0.80	0.15	17.80	
Wheat PI75	14.39	0.49	0.09	10.90	6.90

Source: McAllister et al. 2014 *Using NIRS to predict fecal starch and grain processing index to improve feed efficiency* http://www.beefresearch.ca/factsheet.cfm/using-nirs-to-predict-fecal-starch-and-grain-processing-index-to-improve-feed-efficiency-fact-sheet-a-220 , accessed on April 5, 2017

Using NIRS, McAllister et al. (2014) reported that reducing the processing index (PI) of barley from 85 to 75 resulted in a decrease in fecal starch of 10%, leading to a savings of $4.50/hd over a 120-day finishing period. The researchers also found that there is a fairly wide variation in fecal starch losses across feedlot. This indicates that there is plenty of opportunity for feedlot producers to utilize NIR to estimate fecal starch and adjust processing accordingly to maximize starch utilization. Given the return of $4.50 per head over a 120 day finishing period, with an adjustment of the PI from 85 to 75, the total economic return for a feedlot could be more than the value on the NIR equipment within a single cycle of a 25,000 head finishing feedlot. The economic return increases to $6.90/head per 120 day finishing period when feeding wheat, as increased processing led to a 9% decrease in fecal starch.

Research Opportunities

1. The variation in grain quality and kernel size commercial feed barley emphasizes the challenge in precision feeding of commercial feed barley, and suggests a need to develop a simple way to rapidly and concisely determine the feed value of blend barley (Zhao et al., 2016).
2. Prediction model to quickly determine the feeding value of processed barley will allow producers to optimize processing and modulate starch fermentation in the rumen for improving animal health and performance (Yang et al., 2015).
3. Acidosis index of grain to predict acidosis risk of different barley samples (Yang et al., 2015).
4. Economic research on the cost and benefit of different grain processing strategies and their relationship with cattle performance and acidosis risks.
5. Since barley must be processed for efficient use be cattle, response to grain processing should also be one of the selection criteria to considered in breeding programs.

CORN PROCESSING

Corn grain is the major energy source used in the diets of beef cattle in eastern Canada and the U.S. Owens et al. (1997) compared corn processed by dry rolled, high moisture and steam flaked reported that steam flaking improved energetic efficiency of corn.

Table 7. Corn processing methods and cattle performance

Process	ADG, lb	DMI, lb/d	F:G
Dry Rolled	3.20	20.8	6.57
High Moisture	3.02	19.2	6.43
Steam Flaked	3.15	18.4	5.87

Source: Owen et al. (1997)

The benefit from flaking is due to improved ruminal and total tract digestion of starch (Armbuster, 2006). Unlike barley, the endosperm in corn has two distinct regions, the vitreous endosperm region (higher in flint corn) and the floury endosperm region. Whereas starch in the floury endosperm is readily digested after dry-rolling, the starch in the vitreous endosperm region is surrounded by protein that is extremely resistant to microbial invasion and digestion and consequently the protein and starch in this region of the endosperm often gets through the rumen undigested. More severe processing procedures such as steam flaking are required to breakdown the protein matrix in the vitreous endosperm and make the starch available to rumen microbes (Gibb and McAllister, 2003). Compared to other methods of processing, flaking requires a greater investment in equipment, energy and labor (Armbuster, 2006).

Variables affecting steam flaking include grain type and variety, processing conditions, other diet ingredients, bunk management, feed additives, environment, and cattle type. Regarding processing conditions, flake thickness (density) has more impact than any other variable. Also important are retention time in the steam chest and moisture content at rolling (Armbuster, 2006). Laboratory evaluation provides only limited insight about processing. Fecal starch is a valuable tool, but it is not used widely (Armbuster, 2006).

WHEAT PROCESSING

Whole wheat may be efficiently used by cattle, but it's nutritive value is improved by some form of processing. It is generally conceded that its feeding value is optimized by dry-rolling, coarse grinding or steam-rolling to produce a thick flake. Fine grinding of wheat generally reduces the feed intake and is likely to cause acidosis and/or bloat. Never-the-less, when available for feed, it can be substituted equally for corn on the basis of TDN to a maximum of 25% of dry matter intake for beef (Ontario Agriculture, 2003).

FEED EFFICIENCY

Feed efficiency research develops and validates cost-effective methods to identify more efficient cattle, feedstuffs and feeding strategies. Improving the feed-to-gain ratio (feed:gain) by 1% would save Canada's feedlot sector an estimated $11.6 million annually. At times of high grain prices or forage shortages, feed efficiency plays an even larger role in the value equation. A difference in conversion of one pound represents $90 per head, based on US$4 corn.

A 1% improvement in feed efficiency has the same economic impact as a 3% increase in rate of gain. Weaber (2011) estimated that a 10% improvement in feed efficiency (assumed to be a 2 lb reduction in RFI) across the entire feedlot sector in the U.S. would equate to US$1.2 Billion in reduced feed costs. Applying the same methodology on the Canadian feedlot sector, a 2 lb reduction in RFI would save the industry approximately $80 million in feed cost per year.

Table 8. Potential cost saving for a 2 lb reduction in RFI

In Wt.	Out Wt.	Lb. Gain	ADG	Days on Feed	RFI	Reduced Feed Intake (lb)	Feed Cost Savings ($/hd)	% of Fed Mix	Total Feed Cost Savings
Calf Feds									
550	1,325	775	3.26	238	0	0			
550	1,325	775	3.26	238	-2	-476	-35.05	35%	-$36,798,775
Yearling Feds									
850	1,400	550	3.59	153	0	0			
850	1,400	550	3.59	153	-2	-306	-22.53	65%	-$43,933,231
								Total Savings:	**-$80,732,006**
Annual fed marketings: 3 million head; Feed cost: $0.74/lb									

Adapted from Weaber, 2011 http://www.nbcec.org/FeedEfficiencyBeefCattleISU.pdf

There are multiple aspects of feed efficiency, but broadly speaking there is management and genetic improvement.

BUNK MANAGEMENT *BY: DARRYL GIBB*

To fully appreciate the philosophies of bunk management, a couple of fundamental points to cattle feeding must be recognized: 1) dietary energy drives performance; 2) cost per unit of energy is typically lowest with grains (there are typically economic incentives to maximize grain use).

Bunk management typically refers to strategies of feed delivery that help achieve optimum, stable intakes of all cattle while maintaining digestive health. For backgrounding cattle, this can include strategies to help facilitate limit feeding of higher energy diets to more accurately achieve target gains while capitalizing on reduced costs of production. More commonly, bunk management refers to feeding strategies used in finishing yards to acquire long term, maximum stable intakes through the feeding period. Early research (Fulton et al. 1979) documenting intake and rumen pH fluctuations as cattle were adapted to finishing diets were some of the first to suggest a strong relationship between acidosis and intake fluctuation. Some interpreted this to mean that intake fluctuation can contribute to acidosis. Since then, several trials have confirmed that intake is strongly influenced by rumen pH, and large intake fluctuations can contribute to acidosis. Indeed, engorgement after a period of feed removal is a common practice to induce acidosis in research settings. From work like this, philosophies have evolved of how feed delivery can be managed to improve performance by minimizing acidosis and maintaining stable intakes. Monensin helps moderate intakes through reduced meal size and increased meal frequency (Gibb et al. 2001).

Some who have investigated the topic (Pritchard et al. 1995) have referred to Bunk Management as Acid Management. Therefore, bunk management should not only consider the frequency or time of feed delivery, but also the nature of diet such as forage: concentrate ratio, grain type and processing and forage type and chop length. Managing acidosis is a perpetual challenge for finishing yards that have economic incentive to minimize forage use. Sub-acute acidosis contributes to bloat, reduced intake, liver abscess, and laminitis. A+ liver abscesses alone have been estimated to cost the U.S. feedlot industry an average of $7.42 per animal fed (Schmidt et al. 2002). The 2010/11 National Beef Quality Audit in Canada estimated liver discounts at $9.36 per fed animal or a total of $29.9 million for the industry in 2011[18]. Estimating total acidosis related costs at twice this value is likely conservative.

Reducing these maladies by modifying feed delivery is an attractive theory. However, successes are rarely documented and many of these bunk management principles are driven by logic rather than science. The positive performance response to stable feed deliveries observed by Galyean et al. (1992) has been cited as evidence of the value of consistency in feed delivery. However, such benefits were not observed by others (Zinn et al. 1994, Stock et al. 1995, Cooper et al. 1998, Owens et al. 1998, Soto-Navarro et al. 2000, Hickman et al. 2002). However, consistency in feed delivery seems beneficial to most cattle feeders and is desired by most feedlot managers.

Performance impact

Although there have been several trials documenting the effects of feed delivery on rumen pH (Cooper et. al. 1999); research trials reporting positive effects of bunk management on performance are rare. Justification for investigation is often based on the hope that intakes can be increased by avoiding intake reductions associated with acidosis events. NRC (1996) equations predict that a 5% increase in dry matter

[18] http://www.beefresearch.ca/files/pdf/fact-sheets/nbqa_full_brochure_feb_2013.pdf or http://www.beefresearch.ca/research-topic.cfm/beef-quality-audits-40#liver

intake will result in a 5% increase in rate of gain. Increased gains due to increased intake is consistently supported by research.

Through development and/or early adoption of technologies that record pH (LRC pH data logger (2006)) and feeding behaviours (GrowSafe systems), scientists at AAFC Lethbridge have been leaders in documenting how feed delivery influences feeding behaviours and rumen pH. In a review of how bunk management influences acidosis, Canadian scientists (Schwartkopf-Genswein et al. 2003) documented research that challenges common bunk management dogma, including:

1) variation in feed delivery typically has little impact on performance of pen fed cattle;
2) altering feed delivery has minor if any impact on feeding patterns;
3) best performing cattle may have the most variation in intake;
4) there are huge variations in intake patterns and rumen pH between animals fed the same diet.

One area of bunk management research that has documented a performance response is comparing AM to PM feed delivery (Kennedy et al. 2004, Bergen et al. 2008). Authors believed the performance advantage of the PM feed delivery was due to the heat increment from digestion occurring at night, during the coldest part of the day.

Canadian Research

Canadian researchers continue to use available equipment to record and document feeding behaviour and pH responses. Because of availability of the equipment, this information is often recorded, even in trials where feeding behaviour is not a focus. Canadian researchers are recognized internationally for their work on feeding behaviour (Schwartzkopf-Genswein, McAllister, Beauchemin, Yang) and pH responses to diet and feed delivery (Penner, McAllister).

International Research

International work on acidosis and feed delivery is relevant. However, there are large differences in acidosis potential depending on the type of diet fed. Most international work has used corn-based finishing diets. Western Canada is unique in that barley and wheat are the primary grains fed. There are large differences in intake and rumen fermentation between cattle fed barley/wheat or corn (especially dry-rolled). There is a scarcity of information on the impact of processing on wheat. Consequently, caution must be used drawing conclusions based on corn-based research for barley-fed cattle.

Technology Transfer

Bunk management was a fashionable topic in the late 1990's and early 2000's. Proceedings from many extension type meetings from that era include talks on bunk management. However, much of the promotion occurring at these meetings and in popular press articles were based on simple logic with little sound science behind it. Therefore, caution must be used on drawing conclusions from popular press on the subject.

Monensin reduces meal size and increases meal frequency, helping stabilize intake and moderating pH fluctuations. Thus, monensin has become a valuable "bunk management" tool at the feedlot, allowing higher energy diets to be fed. Based on international trends, it is conceivable that monensin may not always be available. Exploring alternative natural ingredients that similarly alter feeding behavior is justified. For example, recent work evaluating calcium oxide as a feed ingredient demonstrated that it similarly moderates feeding behavior of cattle (Schroeder et al. 2014) while minimizing pH variation, increasing fiber digestibility, and reducing acid load (Nunez et al. 2014). However, these positive effects on digestibility and acid load have not been observed in all trials (Duckworth et al. 2014) and negative effects on intake are concerning (although monensin has a similar effect). It should also be noted that in addition to stabilizing intake and moderating pH fluctuations, monensin can decrease incidence of bloat, coccidiosis, and improve feed efficiency due to manipulation of rumen fermentation, which calcium oxide will not do.[19] Moderating effects on feeding behavior of limit fed cattle have also been observed when calcium hydroxide is included in the diet (Gibb, personal observations). Other areas that influence acidosis such as *grain processing, fibre levels and fibre chop length* deserve further investigation as "bunk management" tools that minimize acidosis.

Pen fed cattle appear to have higher pH than cattle tethered, or confined in metabolism stalls (Penner, personal communication). This may be due to differences in methodology between the two measurements or more disruptive feeding with competition at the bunk for pen fed cattle.

Increased awareness of animal welfare, means it is feasible that minimum fibre levels will one day be a requirement. Even without this constraint, optimum fibre levels in barley- or wheat-based finishing diets have not been well defined. Although reducing fibre levels consistently improves feed efficiency, it also reduces dry matter and energy intakes, and often gains of finishing cattle (Owens et al. 2002). These variables may all interact with feed delivery protocols to influence pH and animal performance.

The ability to document feeding behavior and pH of individual animals, have seen scientists observing large variations between animals in both parameters. This means that 100% of the cattle might be managed to maintain digestive health of a small percent of the animals. For example, if we could identify which animals were susceptible to acidosis challenges, perhaps they could be managed separately enabling the majority to be fed more cost-effective diets.

Research Areas

To monitor impacts of bunk management strategies on feeding behaviour and acidosis, equipment is needed that measures and records feeding behaviour of individual animals in a pen (i.e. GrowSafe) and in-dwelling pH data loggers in animals within a pen (not tethered or confined in a metabolism stall). These systems will answer academic questions that can identify new approaches. However, primary questions at the feedlot level will be answered by performance measurements (i.e. health, intake, gain, and feed efficiency).

Some of the areas of bunk management that justify more research include:

1. There are economic incentives to limit feed high energy diets to back grounded (growing) cattle. It is surprising there has not been more work done to identify ways to manage cattle aggression at the bunk (i.e. frequency, timing of delivery, ingredients that slow down eating rate, etc.). This work may also identify ways to reduce digestive challenges in finishing yards.
2. There are strong opinions of the benefits of multiple feed deliveries. It is surprising there has not been more research done to confirm or refute this simple question.

Further research that links bunk management to:

1. Subclinical acidosis in feedlot cattle;
2. Feed processing and preparation;
3. Feed efficiency and production; and
4. Defining the impact of differences in feeding behaviour of individuals on bunk management and animal health.

The full report by Darryl Gibb is available upon request

[19] Dr. John McKinnon, Draft Review, May 2017

RATION MANAGEMENT

Formulating a ration is a matter of combining feeds to make a ration that will be eaten in the amount needed to supply the daily nutrient requirements of the animal. In addition to being nutritionally adequate, a good cattle ration should be economical, palatable and free of toxic substances (Lalman and Sewell, 1993).

Roughage level and form

Recent research examined the effect of roughage on the control of liver abscesses (LA). Reinhardt and Hubbert (2015) reviewed published literature to provide an overview of the historical prevalence and methods of controlling LA in feedlot cattle. The authors reported that inclusion of physically effective roughage in the diet, in a sufficiently coarse form, and in sufficient quantity that allows development of a robust and persistent fiber mat within the rumen, appears to provide the most reliable control of LA, regardless of degree of grain processing or implementation of other methods of mitigating LA.

Because roughage is costly and difficult to manage in the feedyard, studies should focus on means to maximize the benefits of roughage by altering the timing, level, and form of roughage included in finishing diets (Reinhardt and Hubbert, 2015).

Fat and oil

Finishing feed rations are mainly made up of processed grains. Occasionally fats and oils are added to the grains to make them more palatable and appealing. The fats and oils also decrease the dustiness of rations and thus help to reduce respiratory health problems. The fats and oils are also a very concentrated source of energy and may include oilseeds - including whole canola seed, flax and sunflower - and feed grade vegetable fat, including vegetable oil (CCA[20]).

Previous research examined the impact of oil seed inclusion in finishing diets on cattle performance. Shah et al. (2006) reported supplementation of finishing diets (barley based) for steers with sunflower seeds has little impact on feed conversion efficiency or meat quality. A study by Maddock et al. (2006) showed that feeding 8% flax to feedlot heifers increased gain and efficiency, and processing flax increased available energy and resulted in increased efficiency of gain. He et al. (2013) investigated the effect of substituting canola meal for barley grain (0 (control), 15, or 30%) on growth performance, carcass quality and meat fatty acid profiles of feedlot cattle. The results showed that regardless of diet, cattle did not differ in average daily gain in either the growing or finishing period. Inclusion of canola meal did also not affect carcass quality and incidence of liver abscesses. Castro et al. (2016) reported no differences in growth performance or carcass quality on steers fed with vegetable oil supplements.

Hess et al. (2007) reported that supplementing fat to beef cattle and sheep can be an effective strategy to increase energy density of the animal's diet. Optimal levels of fat in the diet depend on goals set for the production unit. Limiting supplemental fat to 2% of dietary dry matter (DM) will help prevent negative associative effects for ruminants fed high-forage diets. Energy density of high-forage diets will not be increased if supplemental fat exceeds 4% of DM. However, ruminants fed high-concentrate diets may receive up to 6% supplemental fat in the diet without ill effects on utilization of other dietary components.

Segers et al. (2015) examined the effect of fat concentration from corn distillers' solubles, fed during the growing phase, on dry matter intake, gain, carcass traits, digestibility, ruminal metabolism, and methane emissions of steers. The results showed that Increasing dietary fat inclusion from corn distillers' solubles

[20] Canadian Cattlemen's Association, http://www.cattle.ca/resources/animal-care/feed/ , accessed on April 6, 2017

in coproduct based diets linearly increased dry matter and fat digestibility and predicted marbling scores via ultrasound but did not affect marbling at slaughter.

While a number of studies investigated the effect of fat and oil supplements on animal performance, using these fat sources often do not fit into a least cost formulation diet unless they are off grade sources which are not widely available at a level that make them widely available as feedstuff. Economic research is needed to examine the cost and benefits of the inclusion of fat and oils supplements.

Technology Transfer

Recommendations and sample rations are available from a number of sources, for example:

- Alberta Agriculture, Beef Ration Rules of Thumb, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9146
- Manitoba Agriculture, https://www.gov.mb.ca/agriculture/livestock/production/beef/rations-for-finishing-beef-cattle.html
- Beef Magazine.com http://www.beefmagazine.com/nutrition/2016-feed-composition-tables-use-mix-your-cattle-feed-rations?full=1

Alberta Agriculture has a Feed System Cost Evaluator.[21] This calculator compares the costs, on a dry matter basis, of: pit silage, bagged silage, bale silage, and dry hay. It calculates the costs from a standing crop to animal-ready product in the yard, factoring in standing crop value, equipment costs as well as field and storage losses.

Information regarding vitamins and trace minerals is available in the Animal Health and Welfare Priority Review.[22]

GROWTH ENHANCING TECHNOLOGY (GET)

Growth promotants are among the many sophisticated tools used to improve feed efficiency. Growth promotants include ionophores, growth implants, and beta-agonists. A number of products within each category are approved for use by Health Canada's Veterinary Drug Directorate (BCRC, 2016). Information on the common types of GET and their usage, is available in the Priority Area Review: Animal Health and Welfare.

In term of the impact of GET on feed efficiency, studies have shown that GET an important and safe tool for feedlots and other producers to raise more beef, more rapidly, using less feed, while maintaining high standards of animal health, carcass quality and food safety (BCRC, 2016). In terms of economic impact, the use of GET contributes to lower production costs, and improved environmental performance.

Performance and Economic Impact

Canfax data indicate that between 1977 and 2016, Canada slaughtered 30% fewer cattle but produced 16% more beef (including live cattle exports). This indicates the significant improvement in production efficiency in the past 40 years.

Studies conducted in Alberta during 1980s to early 1990s on calves, yearlings and feedlot cattle show that growth implants registered for beef cattle in Canada can increase growth rate by from 5 to 20% and improve feed conversion efficiency by 5 to 10%. The improved performance can provide an extra return

[21] Alberta Agriculture, Feed System Cost Evaluator http://www.agriculture.alberta.ca/app19/calc/livestock/feedingsystem.jsp , accessed on March 7, 2017

[22] BCRC, Animal Health and Welfare Priority Review http://www.beefresearch.ca/files/pdf/bcrc_animal_health_and_welfare_priority_area_review_march2016.pdf , accessed on March 7, 2017

of $7 to $10 for each dollar spent for the growth implant. When these registered implants are properly used, they reduce the cost of production and result in leaner carcasses at any given age or weight (Alberta Agriculture, 2011).

Lawrence and Ibarburu (2008) used meta-analysis to combine over 170 research trials evaluating pharmaceutical technologies in the cow-calf, stocker, and feedlot segment, and reported that growth promotant implants is one of the technologies that affect average daily gain (ADG) the most in stocker operations in the U.S., accounting for 13% of the total impact[23]. The estimated effect on the breakeven price of eliminating growth promotant implants is 2.3% which represents a cost of US$18.19/head (based on 2005 prices). Ionophores has an expected cost of production impact of US$11.51 per head.

For feedlot cattle, growth promotant implants and beta-agonists are estimated to have the largest increase on ADG and Feed to Gain (F:G). Implants resulted in an increase of the ADG by 14.1% and decrease the F:G by 8.8%. Beta-agonists have a similar ADG effect as did implants, but larger F:G impact. In terms of economic impact, implants have the largest cost savings effect or the technologies considered with 6.5% and over US$68/head higher cost if these technologies were eliminated. Ionophores and beta-agonists each reduce costs approximately US$12-13 per head or about 1.2%. The impact of beta-agonists is smaller than reported in their effect in ADG and F:G because they are used for a relative few days at the end of the feeding period.

Wilemand et al. (2009) also conducted meta-analysis and reported that the use of implants in heifers was associated with increased ADG by 0.08kg/day compared to the non-implanted control group, but not associated with the differences in the gain to feed ratio (G:F) or dry matter intake (DMI). The use of implants in steers was associated with 0.25kg/day greater ADG, 0.53kg/day greater DMI and 0.02 increase in G:F relative to nonimplanted control steers. In terms of economic impact, implanted steers were associated with a US$77/animal lower cost of production than nonimplanted steers fed similar diets. In addition, implanted steers fed a nonorganic diet had a US$349/animal lower cost of production than nonimplanted cattle fed and organic diet.

Potential Impact of Removing GET

Despite GET being used to increase feed efficiency and cost effectiveness, their use remains questioned by the general public and is still banned in the EU. In recent years, more research has been around the potential cost of the removal of the technology.

Capper and Hayes (2012) discussed the potential environmental and economic impact of removing growth-enhancing technologies from U.S. beef production. They estimated that withdrawing GET from U.S. beef production reduced productivity (growth rate and slaughter weight) and increased the population size required to produce 454×10^6 kg beef by 385×10^3 animals. Feedstuff and land use were increased by $2{,}830 \times 10^3$ t and 265×10^3 ha, respectively, by GET withdrawal, with $20{,}139 \times 10^6$ more liters of water being required to maintain beef production. Manure output increased by $1{,}799 \times 10^3$ t as a result of GET withdrawal, with an increase in carbon emissions of 714,515 t/454×10^6 kg beef. The projected increased costs of U.S. beef produced without GET resulted in the effective implementation of an 8.2% tax on beef production, leading to reduced global trade and competitiveness. Withdrawing GET from U.S. beef production would reduce both the economic and environmental sustainability of the industry.

Olvera (2016) estimated the potential economic effects of a removal of certain technologies from the U.S. beef cattle production system. The study predicts that the loss of all growth enhancing technologies will have larger implications, with one-year post-ban reductions in fed cattle inventories estimated to be 3.1

[23] Other pharmaceutical technologies reviewed and their effect are: De-wormers (18%), Fly control (8%), Ionophores (8%) and Subtherapeutic antibiotics (7%).

million animals and a corresponding 2.2 billion lb, or a 10.82% reduction in beef production. At five years post ban, beef production and beef consumption are projected to decrease by 10.5% and 8.2%, respectively while beef imports are projected to increase by 9.1%. A lack of domestic production, even with greater imports, drives retail prices up considerably, reducing per capita consumption by 4.37 lb and 3.89 lb per person in year 5 and years 6 through 10, respectively.

Research Opportunities

While there has been research in the U.S. estimating the potential impact of removing GET. This topic has not been extensively studied to in Canada. Given the similarity between the U.S. and Canadian beef production system, the potential costs of removing GET could be similar in Canada. Quantifying the production and economic impacts are relevant for market access and policy making. The benefits that may come back from the elimination of GET in terms of increased EU trade and consumer willingness to pay should also be considered in these studies.

There is also a need for a national tech transfer program aimed at the public that promotes the safety, environmental, economic, production and societal benefits of GET; as well as research that looks at the alternative products or management methods to GET.

PARASITE CONTROL

Internal parasite control plays an important role in beef cattle feed efficiency and profitability. A research by Bauck et al. (1989) conducted a study on 9,527 head of calves in a feedlot in western Canada to evaluate the impact of treatment with ivermectin versus a topical organophosphate on growth rate and feed efficiency. The results showed that the average daily gain (ADG) was improved by 6.5% over cattle treated for external parasites only. The feed to gain ratio (F:G) was improved by 3.0%. These improvements in rate of gain and feed conversion resulted in a net economic benefit of approximately $7.00 per animal.

Lawrence and Ibarburu (2007) evaluated the economic impact of parasite control, growth promoter implants, sub-therapeutic antibiotics, ionophores and beta-agonists. The study found that, of these practices, deworming had the biggest positive impact in cow-calf (23% for weaning rates), stockers ($20.77 per head in breakeven prices) and the second highest benefit after growth promoter implants at the feedlot (5.6% improvement in ADG and 3.9% improvement in F:G).

In the 2014 Western Canadian Cow-calf survey, 71% of survey respondents responded to the question about parasite treatment. Of these respondents, 93% treated their cattle for lice and 82% for internal worms (82%). Less than half treated for flies (46%), approximately one quarter (26%) treated for ticks and 17% treated for liver fluke (WCCCS 2014). The Health Management and Biosecurity in U.S. Feedlots (1999) reported 96% of the feedlots treat for parasites shortly after placement in the feedlot. While there is no published number for Canadian feedlots, it is believed that parasite control is also widely used in Canada.

The beef industry has relied on the use of pour-on macrocylic lactone drugs (e.g. ivermectin) to control GIN parasites for the last 30 years (Gilleard, 2016). These anti-parasitic drugs have provided producers with major production benefits. From 2012 to 2016, Canadian fed cattle marketings averaged at 2.7 million head annually. Assuming these cattle's average weight-gain in the feedlot is 550 lb/head (in-weight 750 lbs, out-weight 1,300 lbs), the total weight gain is estimated at 1.5 billion lbs. If we also assume an average F:G ratio at 6.5, the total feed required is about 9.8 billion lbs. A 3-4% increase in F:G ratio to 6.7-6.8 as a result of the lack of parasite control would mean an additional of 250-400 million lbs of feed needed annually to feed these cattle. Costing the beef industry an estimated $25-40 million at $220/tonne for barley (2012-16 average).

Resistances to the macrocyclic lactones, as well as other anthelmintic drug classes, have emerged worldwide and now threaten sustainable parasite control (Gilleard, 2016). Obtaining information on the prevalence of drug resistance, developing optimal treatment options will be important research areas for the beef industry. In addition, investigating producer perceptions and developing policies to maximize the adoption of new technologies is also important.

Cost-benefits analysis on different parasite control strategies (e.g. using Ivomec for external and Safeguard for internal parasites; using pour-on macrocyclic lactone drugs to control internal parasite) is needed.

A detailed discussion on research priories on parasite control by Dr. John Gilleard and Dr. Doug Colwell is available in the BCRC Priority Area Review for Animal Health and Welfare[24].

ANIMAL GENETICS

The value associated with Marker-assisted selection (MAS) is generally small at the feedlot for key profit determinants including: yield grade ($0.03/head), marbling ($0.35), average daily gain ($0.20) and hot carcass weight ($0.10/head) (Thompson et al. 2014). Low values are partially influenced by limited difference among optimal days on feed for the quartiles of each trait and the uniform endpoint for all cattle in the sample (Thompson et al. 2014). If a feedlot could differentially select cattle based on genetic information for each trait (assuming that there were no negative interactions among selection for these traits), expected profits could be increased considerably. The ability to select for animals with higher average daily gain will result in heavier finished weights and/or fewer days-on-feed, both of which increase profitability. the value associated with selecting and feeding cattle based on genetic potential is rather high (as much as $22 per head for single-trait selection and $38 per head for multiple-trait selection). These results are similar to the findings of Lusk (2007) who reports values of marker-assisted selection at the feedlot stage for leptin genotype of approximately $23 and $28 per head for steers and heifers. Given the small margins, these values represent significant economic value to the cattle feeding sector. However, the current cost of a profile of marker panels that includes each trait is $38 per head, completely offsetting the gains outlined and making marker-assisted management infeasible at the feedlot (Thompson et al 2014). Declining costs may lead to cost-effective options in the future.

Breeding Selection

Selection for the wide range of traits for which most beef breed associations calculate expected progeny differences (EPD) focus on increasing the outputs of the production system, thereby increasing the genetic potential of cattle for reproductive rates, weights, growth rates, and end-product yield (Crews, 2004). However, as 70% of beef production costs are feed related, genetic improvement programs should include traits related to feed efficiency to reduce input costs (Nielsen et al. 2013). Therefore, reducing energy for maintenance is a clear target for genetic improvement programs. However, the focus of these programs should not be to define a single measurement of efficiency, but to define optimal measures that conform to the marketing practices in the industry.

Differences between animals in feed required per unit of metabolic body size, including those due to genetics or breeding value that can be changed via selection, have been demonstrated in mice (Nielsen et al., 1997). The magnitude of these differences is relatively large enough to imply that reduction of 15 to 20% in maintenance costs would be achievable through long-term selection (Nielsen et al., 2013).

The Challenges

[24] Available at http://www.beefresearch.ca/research/animal-health-welfare.cfm

Feed efficiency is a genetically complex trait involving many genes and interactions. There are thousands of genetic markers for feed efficiency. Currently there is little information on what most of the genes are or what they do. If producers were able to make accurate genetic selection decisions sooner, industry could make big changes much faster. Those could either be positive through improved feed efficiency or negative through changes in structural soundness. Unintended consequences through breeding and genetics is a concern. *What are the impacts on quality grade and tenderness in progeny? What are the impacts on fertility and longevity in replacement breeding stock?*

Residual feed intake (RFI) requires individual animal information that has been to date costly and not practical to collect on a commercial scale. Despite being touted by researchers since the 1960s as being able to provide detailed information for genetic selection it has not been adopted by industry.

Current Research

DNA markers (e.g., single nucleotide polymorphism (SNP) and microsatellite) are considered to be a potential tool for genetic improvement in beef cattle and other species. A study by Abo-Ismail et al. (2011) aimed to identify genetic markers responsible for genetic variation in feed efficiency traits as well as to understand the molecular basis of feed efficiency traits. The study developed a small SNP panel for feed efficiency. A larger-scale, on-going project – Whole Genome Scan for Feed Efficiency[25] – funded by BCRC and led by Dr. Stephen Moore aims to use the 50,000 SNP chip to identify DNA markers associated with feed efficiency, to improve the reliability of DNA tests for feed efficiency.

In the U.S., a multiyear USDA funded project - the National Program for Genetic Improvement of Feed Efficiency in Beef Cattle (www.beefefficiency.org) – aims to develop selection tools and better understanding of feed efficiency in beef production. The project involves a consortium of scientists, industry partners, breed associations, and cattle producers who will collect DNA samples and feed intake, growth, and carcass composition data from over 8,000 animals (8 breeds).

A Feed Efficiency Calculator[26] tool was developed by the program. This calculator is an Excel based application that allows Bull or Heifer Developers to calculate the Raw Feed to Gain, Adjusted Feed to Gain, Residual Feed Efficiency, Residual Gain and Feed Efficiency Index on tested contemporary groups.

Current research also shed light to the optimum measurement period for evaluation feed intake traits in beef cattle. Culbertson et al. (2015) found that a testing periods of 42 days for determining average daily dry matter intake (ADMI) and 56 days for RFI could ultimately reduce testing costs and result in collection of data on a larger number of animals per year, in turn resulting in more data for genetic evaluation.

Research Opportunities

Rumen Biology: a greater understanding of rumen biology will inform residual feed intake (RFI) of cows and feedlot feed to gain. This is the best measure currently available for metabolic efficiency, or energy conservation because it is independent of body weight, average daily gain and backfat thickness.

Interaction with other traits: feed efficiency is a genetically complex trait involving many genes and interactions with other traits, and their relationship is not well understood. The economic impact of a 10% improvement in RFI on other production trait is unclear. A better understanding on the interaction of feed efficiency trait DNA marker with other production traits will be important for making accurate genetic selection decisions.

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[25] Finding DNA Markers for Feed Efficiency http://www.beefresearch.ca/factsheet.cfm/finding-dna-markers-for-feed-efficiency-77 , accessed on March 2, 2017

[26] Available at http://www.beefefficiency.org , accessed on March 2, 2017

Feeders versus breeding females: Nielsen et al. (2013) reported that one of the challenges that need further research is to assess and understand the genetic correlation between feed energy requirement for maintenance per unit size in a growing calf in a feedlot, which consumes a high proportion of grain, versus in a reproducing cow, which consumes mostly forages in a range or pasture environment.

Replacement female selection: While research has shown positive genetic relationships between growing calf and reproducing cow energy requirements. The data on feed intake and utilization on heifers, before making replacement selection decisions, is lacking. Therefore, more study is needed to appropriately account for the associations of feed intake and other economically relevant traits in the female (Nielsen et al. 2013).

Cow forage efficiency: Forage is the basic resource of the beef industry that no other species can use for economic and productive purposes. An area that we have not addressed in feed efficiency research is how do we select for more forage efficient cows – cows that can consume large volumes of low cost forage, maintain condition, and have high reproductive efficiency. [27]

Feed intake measurement: A major challenge for beef producers to select for more efficient animals is the difficulty in measuring individual feed intake (Ontario Agriculture). While there are sophisticated technologies available, measuring individual animal feed intake is an expensive and time-consuming process. More efficient and lower-cost data collection methods could support studies on genetics and feed efficiency. Measuring feed intake of grazing cows is not easy, but improving the efficiency of feed utilization of cows is still of paramount importance. Thus, either protocols for measuring intake at grazing, or indicator traits indicative of intake at grazing, need to be identified to maximize improvement in production system efficiency (Nielsen et al. 2013).

[27] John McKinnon, Draft Review, May 2017

MANURE MANAGEMENT BY: ROSS H. MCKENZIE

Management of livestock manure is an increasing challenge facing the intensive livestock industry. The major **environmental** concerns of livestock manure include the potential risk of nutrient accumulation in soil, particularly nitrogen (N) and phosphorus (P); and the potential risk of nutrient contamination in surface water and groundwater. The major **agronomic** concerns of livestock manure include: 1) Over application of N in manure will increase agronomic problems such as increased crop disease pressure, crop lodging, crop yield loss and reduced crop quality; 2) Excessive levels of N, P or potassium (K) in soil can cause toxicity and nutrient imbalance issues with crops to reduce soil quality and reduce crop yields; 3) Excessive manure application can increase soil K levels that can negatively affect soil physical quality.

It is increasingly important for livestock operators to use recommended management practices (RMP) to prevent environmental or agronomic problems from developing. RMP's will vary from farm to farm and region to region; and need to be tailored to balance the nutrients in manure with the crops grown on each farm. However, it is virtually impossible to apply manure to exactly meet the crop requirements for all nutrients; and the major challenge is that the nutrient content of feedlot manure does not match the nutrient requirements of most crops.

From an environmental standpoint, it is advised that feedlot manure should be managed based on P nutrient content versus N content when developing a long-term manure management plan. When feedlot manure is applied to meet the N requirements of a crop, P will be applied at approximately three to six times the rate of crop removal. Repeated applications over a period of years will result in a buildup of high soil P levels.

To date, only the province of Manitoba has developed legislation to control maximum soil P levels in agricultural soils. The province of Alberta considered instituting soil P limits in 2007, but in the Paterson et al. (2006) summary report, it was recommended to wait 5 to 7 years and then review the need for soil P limits. The hesitation to recommend soil P limits was because many feedlot operations only have a land base large enough to dispose of the N in manure and balance N application with crop up take requirements. If soil test P limits were imposed, this would mean many feedlots would need to increase their land base by three to six times to balance the amount of P in manure produced with crop uptake and removal. This is a major issue and a great challenge for feedlot operators in western Canada.

Canadian Research

Feedlot manure research has been ongoing at the AAFC Research Centre near Lethbridge, AB since the 1970's. Chang and Hao (2005) prepared an extension paper summarizing some of the important results and lessons from this study after 30 years including: 1) Animal manure is an excellent crop nutrient source; 2) Nutrient management for animal manure is very complicated; 3) Crop nutrients could be potential contaminants for soil, water and air; and 4) Improper management of animal manure could cause negative environmental impacts.

Alberta Agriculture has also conducted a number of studies with feedlot manure. These studies covered topics from the examination of manure application on irrigated medium and course textured soils in southern Alberta (Olson et al. 2003), to an extensive review of soil phosphorus (Alberta Agriculture 2007[28]).

Recent studies have also examined the different manure handling and application methods. Considerable composting research has been conducted at AAFC Lethbridge Research Center by Dr. F. Larney and co-workers. Another recent beef manure research project was conducted in Manitoba by the Manitoba Beef

[28] Alberta Soil Phosphorus Limits Project, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag11864 , accessed on April 3, 2017

Producers. Part 1 was conducted by Undi et al. (2011) at the University of Manitoba and examined solid cattle manure handling by beef producers. Part 2 was beef manure research conducted by Kumaragamage et al. (2011) at the University of Manitoba and AAFC at Brandon. This study examined beef manure application on forages and annual crops for three years.

The results of these studies indicate that while composting is a great idea in theory, it has not proven to be economical for most feedlots. To balance P application in manure with crop use, most feedlot operators would have to increase their land base and/or transport their manure farther distances from their feeding operation. To purchase sufficient land to balance manure nutrients with crop nutrient use, would be costly and may not be practical for many feedlot operations. Working with neighbours to provide manure as a fertilizer and soil amendment is an excellent option. This may mean additional transportation costs to the producer. But if the manure is provided free or for a nominal charge to nearby neighbors, and the neighbors could pay for transportation costs, this would be a win-win for both the feedlot operator and neighbors. Presently, most feedlot operators find that it is not economical to transport feedlot manure more that about 10 to 12 km. Beyond this distance, the time and expense for transportation becomes greater than the nutrient value of the manure.

Technology Transfer

Considerable technology transfer information has been developed and is available from by the Alberta, Saskatchewan and Manitoba provincial departments of Agriculture individually and jointly as part of the Tri-Provincial Manure Management initiative. Alberta, Saskatchewan and Manitoba each have prepared their own Tri-Provincial Manure Application and Use Guidelines. Introductory information and detailed information on manure planning and management can be found in various provincial government resources, such as:

- Alberta Agriculture, Manure Management
- Saskatchewan Agriculture, Managing Manure as a Fertilizer
- Manitoba Agriculture, Manure Management

Computer programs have been developed:

- Alberta Agriculture, Manure Management Planner (MMP) 2011
- Manitoba Agriculture, Manure Application Rate Calculator (MARC) 2008

Future Research Needs

Beef feedlot manure has received considerable research attention. An excellent understanding of nutrients in manure, and the fate of nutrients in soil has been developed. From this extension information has been developed. Some suggested further research topics include:

1. Develop and test equipment and technologies that can economically apply manure at rates that meet annual crop phosphorus requirements and reduce loss of manure nutrients during application;
2. Further develop and assess environmentally effective beneficial management practices that producers can economically and practically implement; and
3. Further examine maximum phosphorus limits for runoff from agricultural land and receiving streams and rivers.
4. The implementation of soil-test phosphorus limits may result in significant financial hardship to the intensive livestock industry, particularly the beef feedlot industry. Additional research and policy analyses are needed to develop alternate methods of managing excess manure from existing operations.

5. A new economic study to evaluate the cost of transporting fresh manure and composting manure based on current fuel, labor, trucking costs versus commercial fertilizer use would be beneficial.
6. Apply manure used variable rate technology to more effectively match and utilize nutrients in manure and in variable soils.
7. Up to 70% of the nitrogen fed to animals is lost as ammonia from the pen floor and lagoon. This represents a huge loss in fertilizer value of the manure. Methods to improve feed nitrogen utilization by cattle, and to decrease nitrogen excretion, and ways of reducing nitrogen losses from the pen and stockpiled manure are needed[29].
8. Studies on the role of manure in soil reclamation, particularly areas where significant organic matter has been lost.[30]
9. Links to manures ability to promote carbon sequestration.

The full report "Overview of Manure Nutrient Management"
by Ross H. McKenzie is available upon request.

[29] Dr. Karen Beauchemin, draft review, May 2017

[30] Dr. Tim McAllister, draft review, May 2017

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