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Proceedings

Trends and Opportunities in Reducing the Environmental Footprint of Dairy Farms

T.A. McAllister[1], S.J. Pogue[1] and S.A. Terry[1]

[1]Agriculture and Agri-Food Canada Research Centre, Lethbridge, Alberta, Canada T1J 4B1
E-mail: tim.mcallister@agr.gc.ca

Take Home Messages

- Dairy farm footprints should be considered from a systems perspective.
- Greenhouse gases are part of, but not the only component of the footprint.
- Footprint reduction technologies need to consider all footprint components.
- Improving efficiency of crop production or milk production will reduce the overall footprint of dairy farms.

Introduction

Producing milk to satisfy the growing global demand for protein by humans requires a thorough understanding of how dairy farming systems can meet this goal without compromising economic, environmental, and social sustainability. Understanding the environmental footprint of dairy farms is a key component in having a positive impact on ecosystem services. Greenhouse gas (GHG) emissions are often the focus of the footprint, but other factors such as water quality, soil health, nutrient flows and biodiversity also need to be considered. Consumer expectations regarding sustainable production practices that minimize the environmental footprint of dairies continue to increase. Optimizing the footprint of dairy production can be addressed through a social-ecological approach to ecosystem service assessment, which assesses the linkages between the different agricultural-social-ecological components of dairy production systems (Figure 1). Improvements in feed efficiency are likely to result in the greatest reduction in the milk production footprint. Feed efficiency is a complex trait because it is influenced by feed quality, digestive tract microbial populations, production environment and the genetics of the cow. This paper provides an update on the interactions among the various factors that determine the environmental footprint of milk production and outlines some of the emerging technologies that can be used to reduce its environmental footprint.

Greenhouse Gas Footprint

Globally, livestock are responsible for about 40% of agricultural GHG emissions arising directly from the animal and from manure (Figure 2). Ruminants produce methane as a natural by-product of the microbial fermentation of concentrates and forages within the rumen. Both primary and secondary microorganisms in the rumen convert these feeds into volatile fatty acids (VFA), carbon dioxide and metabolic hydrogen. Methanogens play an important role in maintaining a low partial pressure of hydrogen in the rumen by reducing carbon dioxide to methane (Leahy et al., 2022). Consequently, methane production plays a key role in the fermentation process and its production is thought to be necessary for efficient feed digestion.

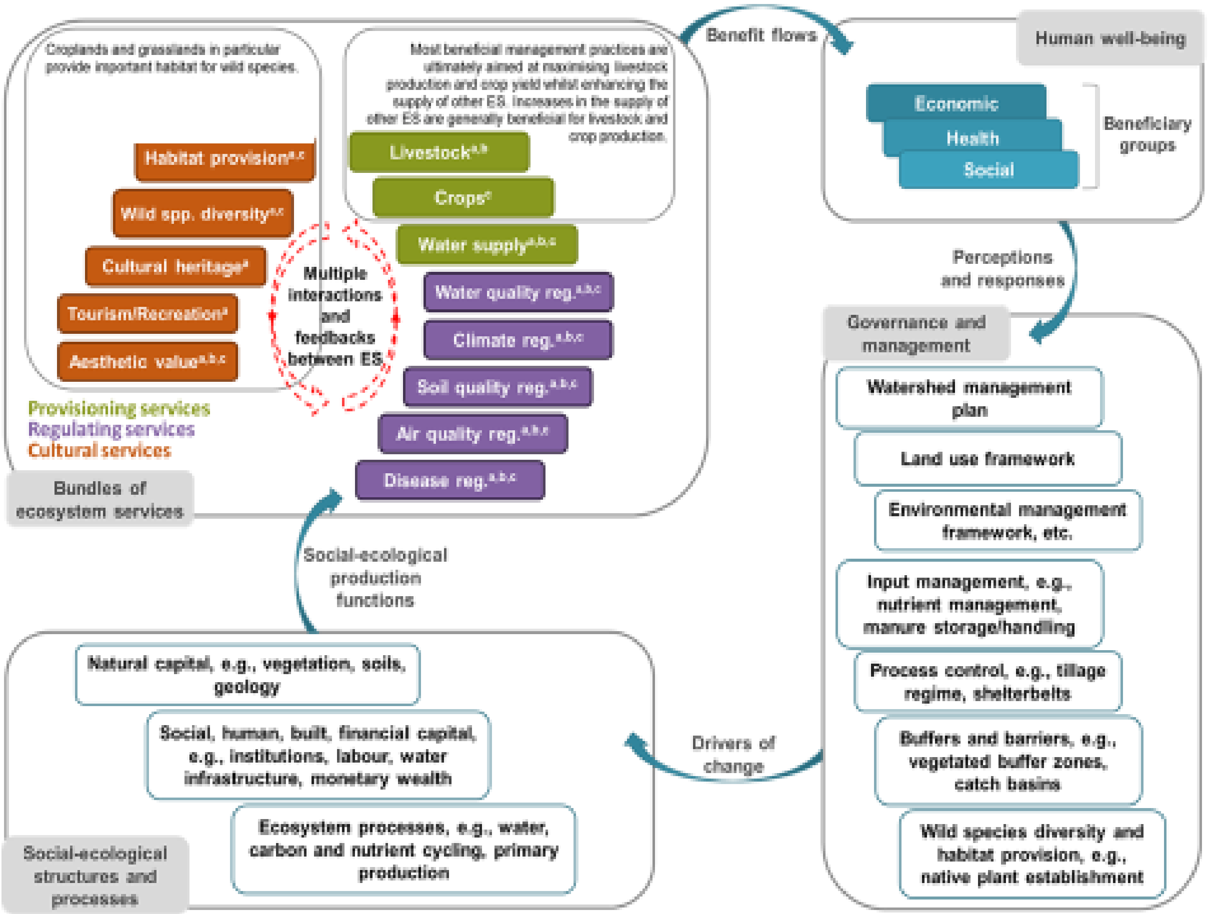

Figure 1. Conceptual ecosystem service framework for Canadian dairy production systems (Pogue et al., 2018).

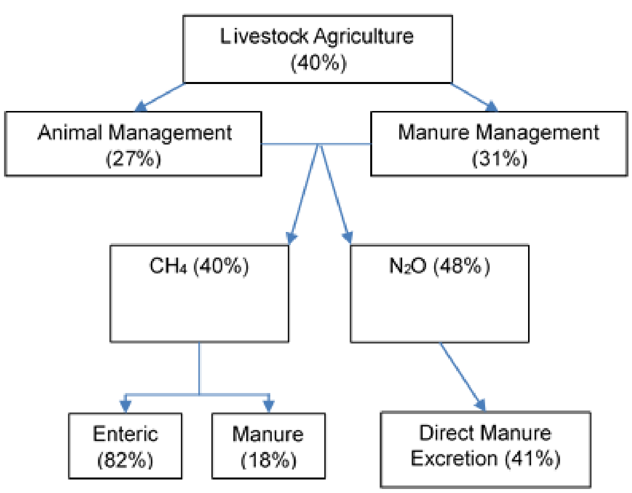

Figure 2. Greenhouse gases associated with global livestock production (Terry et al., 2020).

Methane can also be produced from dairy manure in lagoons or liquid storage structures. Sealed biodigesters can enable methane produced from dairy manure to be captured and used for heating or to generate power but require considerable capital investment and must be continuously monitored to ensure there is no leakage.

Manure can also be a significant emitter of nitrous oxide and ammonia. Factors that influence the concentration of greenhouse gases produced from manure include the type of feed, manure nutrient profile, and manure handling and storage practices. The conversion of nitrogen into gases occurs through simultaneous nitrification and denitrification processes. Nitrate is a valuable source of nitrogen for plant growth, but in excess it can also contaminate surface and ground water.

Although not a direct source of GHG, ammonia emissions from manure should also be considered when assessing the impact of management practices on air quality. Ammonia arises from the rapid hydrolysis of urea in urine and can also be a precursor to nitrous oxide. Ammonia is highly volatile and can start to cause respiratory stress to cows when concentrations in the air exceed 35 ppm. Additionally, excess levels of ammonia in soil can contribute to soil acidity and its flow into ground and surface waters can lead to eutrophication. Shifting the excretion of nitrogen from urine to feces may be more environmentally beneficial as fecal nitrogen is released at a slower rate and is more likely to be captured by soil flora and used to support plant growth. Understanding the carbon and nitrogen cycles within dairy production systems is essential to maximizing the amount of carbon, nitrogen and other nutrients that are captured in crops, milk, and meat. This reduces the movement of pollutants into the atmosphere and ground and surface water (Figure 3).

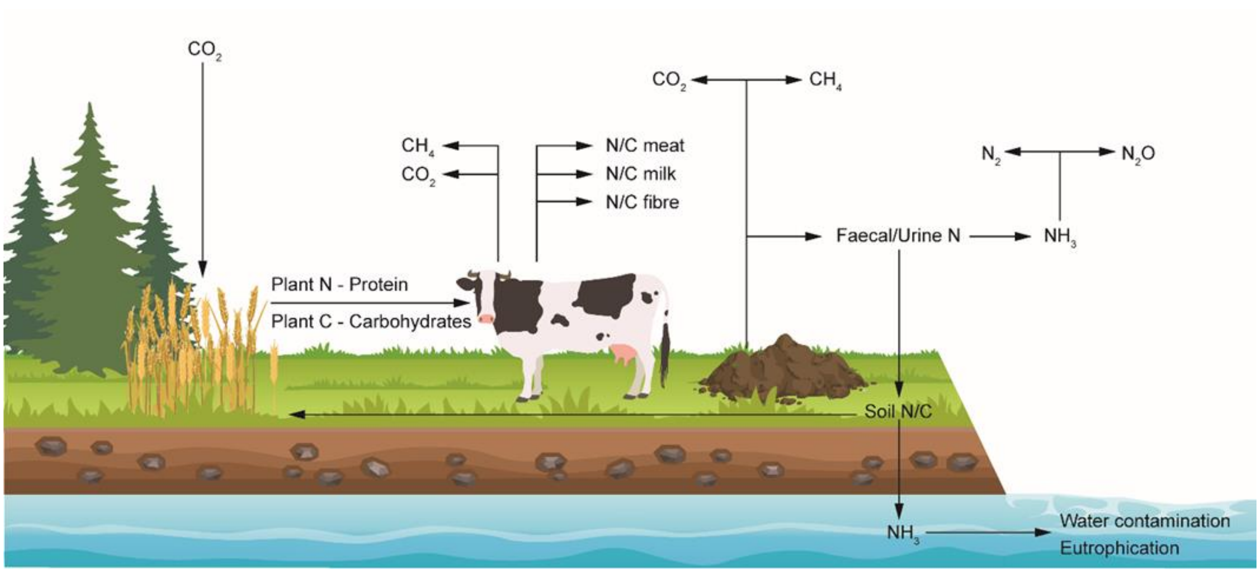

Figure 3. Carbon and nitrogen cycle in dairy cow production systems. Environmental footprint of dairy cattle production is reduced by maximizing the amount of nutrients (e.g., carbon, nitrogen, and phosphorus) that are captured by soil fauna, crops, milk, and meat (Terry et al., 2020).

▪ Reducing the Greenhouse Gas Footprint

Several approaches have been explored for their ability to lower GHG emissions from ruminants (Figure 4). Strategies targeted at reducing GHG emissions need to consider their impact on emissions throughout the dairy production cycle. Furthermore, their implications on production efficiency also need to be considered. For example, increasing the level of concentrate in the diet can reduce the intensity (methane/L of milk) of methane emissions in dairy cows, but this approach needs to be balanced against the risk of a decline in fibre digestion, rumen acidosis and milk fat depression. Any factor that lowers milk production will result in an increase in GHG emissions on an intensity basis.

	ENTERIC							MANURE					OVERALL	
DIETARY CHANGES	Fermentation	Fibre Digestion	N Digestion	Starch Digestion	pH	CH_4 PRODUCTION DAILY	CH_4 INTENSITY	Starch	Urine N	Faecal N	CH_4 EMISSIONS	N_2O EMISSIONS	DECREASE IN GHG PRODUCTION	DECREASE IN GHG INTENSITY
Concentrate/Forage														
Increased Concentrate/Forage	↑	↓	NA	↑	↓	~	↓	↑	NA	NA	↑	↑	~	✓
Acidosis	↑	↓	NA	↑	↓	~	-	~	NA	NA	~	~	~	~
High Forage	↓	↑	NA	↓	↑	↑	↑	↓	NA	NA	↓	↓	~	×
Nitrogen														
DDGS	~	↑	↑	~	~	↓	↓	↑	↑	↑	↑	↑	×	×
Fat														
< 6%	~	-	NA	-	~	↓	↓	-	NA	NA	-	-	✓	✓
> 6%	↓	↓	NA	~	↑	↓	-	↑	NA	NA	↑	~	✓	×
Inhibitors														
Nitrate	~	-	-	~	-	↓	↓	~	~	~	~	~	✓	✓
3NOP	~	-	-	-	~	↓	↓	-	~	~	-	-	✓	✓
PSC														
Tannins	↓	↓	↓	NA	NA	~	~	~	↓	↑	↓	↓	✓	~

Figure 4. Consequences of dietary manipulation on enteric production and greenhouse gas emissions. Symbols indicate: ↑ = increase, ↓ = decrease, - = no change, NA = not applicable, ~ = variable/unknown (Terry et al., 2020).

Other approaches such as adding dried distillers grains with solubles to the diet can lower rumen methane production owing to its oil content, but if it is not fully digested or increases the level of dietary protein above requirements, it can increase methane and nitrous oxide emissions from manure. Similarly, addition of oils to the diet at levels < 6% of diet can lower rumen methane emissions. However, at levels > 6%, fats can suppress fermentation and fibre digestion, lowering milk production and actually increasing emissions per L of milk. Oils are also expensive and do not always fit into the diet as a least cost energy source. Considerable research effort has also gone into the identification of methane inhibitors such as nitrate and 3-nitrooxypropanol (3NOP). Nitrate acts as an alternative electron acceptor, and its reduction to nitrite and ammonia in the rumen is thermodynamically more favourable than the reduction of carbon dioxide to methane by methanogens. However, nitrite can be toxic as it inhibits the ability of red blood cells to transport oxygen, making it unlikely that it will be used as means of reducing ruminal methane emissions. 3NOP has been shown to decrease rumen methane emissions by up to 80% and is commercially produced by the DSM corporation. 3NOP has been approved for use in cattle in Brazil and Argentina and is undergoing regulatory evaluation in the United States, Europe, and Canada.

A large variety of plant secondary compounds from a diverse range of plants have also been explored for their potential to mitigate enteric methane emissions. Secondary metabolic compounds commonly employed as feed additives include essential oils, saponins and tannins. However, over 200,000 defined phytochemicals have been identified and many have been assessed for their ability to lower methane emissions in laboratory experiments. A comparatively smaller portion of these have been tested in the animal, with many being deemed undesirable because of potential toxicity or their lack of palatability.

Tannins are in forages such as sainfoin and birdsfoot trefoil, with a number of tannin-rich forages having been shown to reduce ruminal methane emissions. Tannins can also alter protein digestion in ruminants, shifting the flow of nitrogen from the urine towards feces. When effective, tannins could reduce GHG emissions from both the animal and manure. However, care must be taken to ensure that they do not reduce ruminal methane emissions by lowering overall digestibility or nitrous oxide emissions by lowering protein digestion to the point that they compromise milk production.

▪ Water Footprint

The water footprint can be described as three water types: green water, which is snow or rainwater, blue water, which is surface or ground water, and grey water, which is water that is used to dilute and transport nutrients and pollutants (Figure 5). The majority of water used in dairy production (> 90%) is associated with crop production. Consequently, strategies that reduce the use of water in feed production are likely to have the greatest impact on reducing overall water use. Water use by crops can be reduced by switching to more drought tolerant crops or breeding for drought resistant varieties. Where crops are irrigated, switching from open canals to closed pipelines and improvements in nozzle design can further reduce blue water use. Typically, water consumption by the animal accounts for < 10% of the footprint. In Canada, it has been estimated that it requires 6-8 L of blue water use in barns to produce a litre of fat and protein corrected milk. Wastewater can be a significant use of blue water within dairy barns, and recycling plate cooler and milk house water has been estimated to reduce in-barn use of blue water by as much as 20% (Al-Bahouh et al., 2021). Ensuring that there are no leaks in water troughs and pipes, and optimizing floor flush systems can further reduce blue water use. Minimizing the production of excessive nutrients by reducing the amount of manure that is produced can lower the amount of grey water used. In the future, higher ambient temperatures as a result of climate change could increase water use by both crops and dairy cows. In-barn use of blue water could also increase if sprays are required to cool the barn as a means of reducing heat stress in dairy cows.

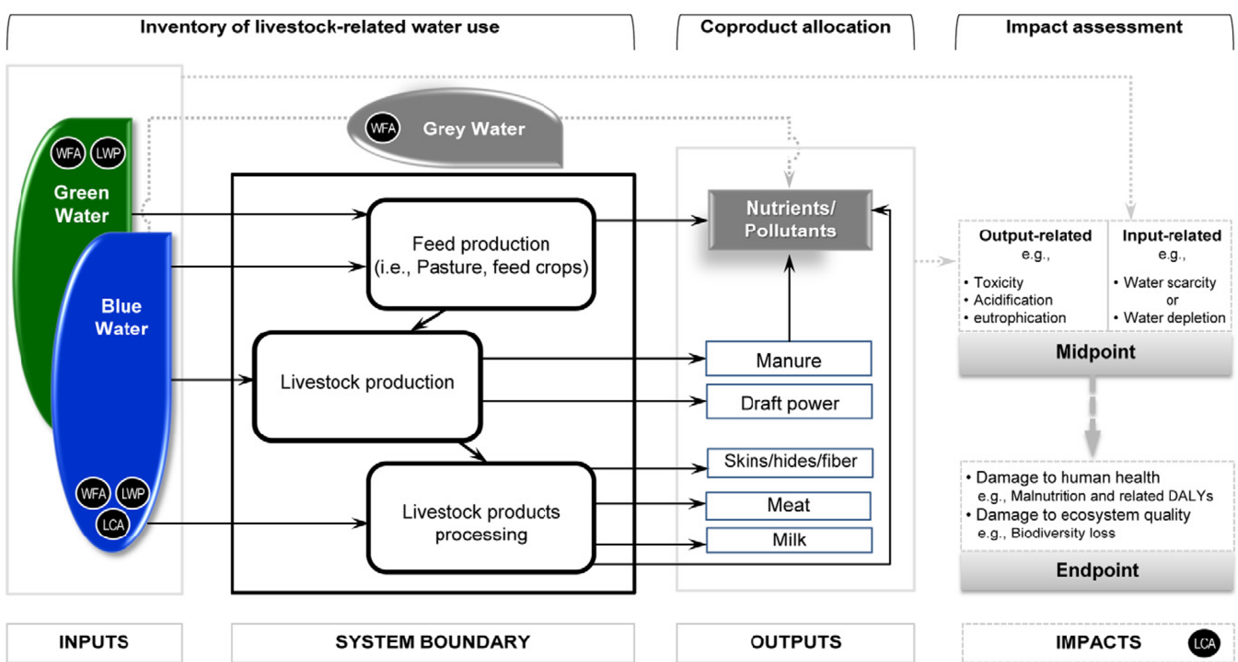

Figure 5. Approaches to the assessment of the water footprint in ruminant productions systems. The model would consider all water used to produce a L of milk. Improving the efficiency of blue and grey water use offers the easiest approach to reducing the water footprint of milk production. (Legesse et al., 2017).

▪ Biodiversity Footprint

Adequate biodiversity is an essential trait of adaptive and productive ecosystems. Land use change such as the conversion of grasslands and forests to croplands is typically the greatest driver of biodiversity loss. For example, conversion of grasslands to croplands reduces soil diversity by decreasing the abundance of mosses, lichens, and soil mites. Perennial forages and grazing systems have greater biodiversity than continuous cropping systems, but often at the expense of lower crop and milk yields than mixed concentrate – forage diets. Consequently, dairies can make the greatest contribution to biodiversity by ensuring that the vast array of fauna that contribute to soil health remain active (Figure 6). Manure can play a key role in promoting soil biodiversity and health because it contains an array of substrates for soil fauna. However, care must be taken to ensure that the application rate of manure does not exceed the nutrient requirements of soil fauna or the crop, so as to avoid the flow of nutrients into ground and surface water. Unlike chemical fertilizer, manure directly increases soil organic matter.

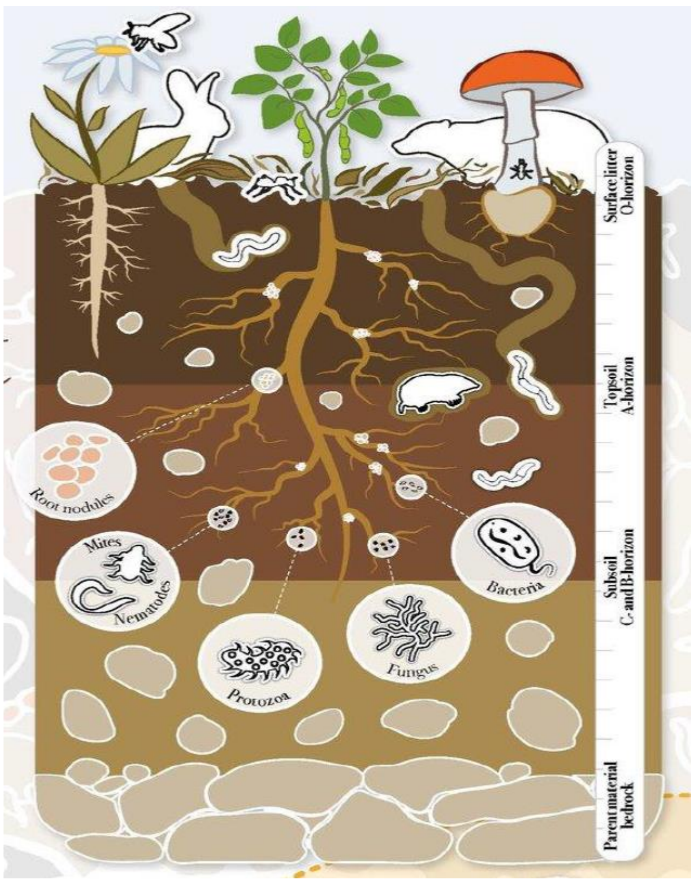

Figure 6. Confined dairies can optimize their biodiversity footprint by ensuring a rich diversity of fauna which contribute to soil health. Proper manure management plays a key role in this process. Increasing the use of perennial forages and grazing can also enhance biodiversity. Adapted from Global soil biodiversity initiative (https://www.globalsoilbiodiversity.org/resources-1).

▪ Efficiency and the Environmental Footprint

Canadian dairy farms already have one of the lowest carbon footprints for milk production in world (Figure 7). The continued reduction in the footprint of Canadian dairy production will arise as a result of improvements in system efficiency. This efficiency can arise from various points throughout the dairy production system. For example, improvements in crop yields can reduce the amount of land required for crop production and increase the extent to which nutrients in chemical fertilizers and manure are captured by the plant. This in turn can reduce the water footprint because less blue water is required for crop production and less grey water is needed for nutrient disposal. Genetic selection for improved feed efficiency reduces the amount of feed required by the cow and the amount of manure produced. This can also result in the reduction of the amount of land required for feed production. Land that is not required to produce feed can remain as perennial grassland so as to promote biodiversity in these threatened ecosystems. Consequently, it is critical that approaches to reduce the footprint of dairy production do not compromise the efficiency of milk production because such practices will increase, not decrease, the overall footprint.

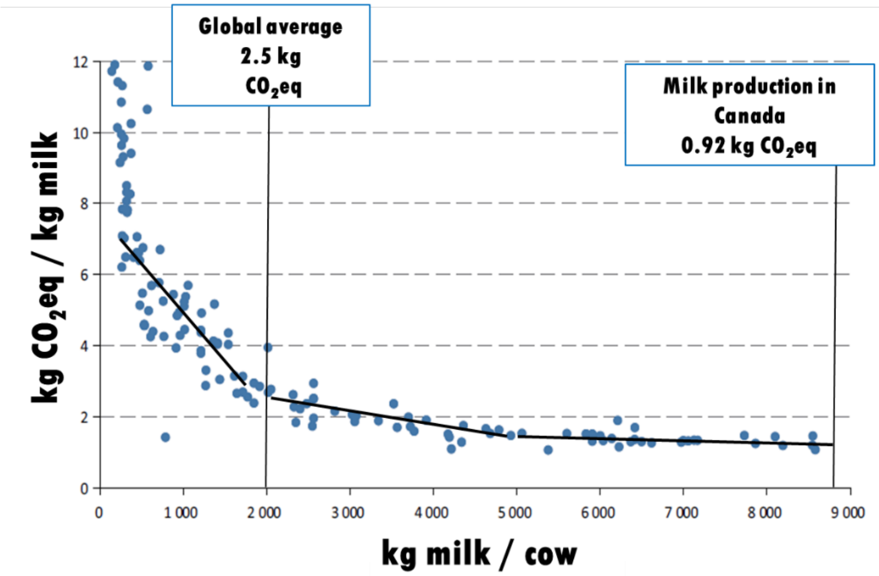

Figure 7. Carbon footprint of Canadian milk production compared with the global average. Any factor that lowers milk production will result in an increase in the footprint of dairy production on an intensity basis.

▪ Conclusion

Characterizing and defining the footprint of livestock products is becoming increasingly common because retailers and consumers wish to know the contribution of livestock to climate change. Canada's dairy industry already has one of the lowest carbon footprints for milk production in the world, but to sustain consumer confidence the industry needs to continue to strive for improvement. Improvements need to be implemented from a systems perspective, with attention paid to footprint factors other than just GHG emissions. To some extent, most Canadian dairy production systems are sheltered from climate change as cows are housed within controlled environments. However, as was aptly demonstrated by the latest floods in the Fraser valley, even these systems are not immune to the impacts of climate change.

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Building Public Trust in Food and Farming

Kim McConnell CM

Founder and Former CEO, Ad Farm, Okotoks, Alberta, Canada
Email:Kim@KimMcConnell.ca

Take Home Messages

- It's a changing world … and agri-food is in the middle of it. Our food has never been safer, yet consumers have never been more concerned.
- Food affordability and sustainability are top of mind. Consumers want healthy, affordable food … and food inflation is causing concerns for many Canadians. Additionally, sustainability and the environment remain high priorities for Canadians.
- Trust in our food system cannot be taken for granted. After considerable improvement in 2020, research shows there was a significant decline in the number of Canadians who feel the food system is headed in the right direction.
- Big picture first. Canadians are interested in improving the agri-food system as a whole and somewhat less interested in intricate details or specific issues related to agriculture and/or food production.
- Canadians trust farmers. Canadians continue to trust farmers, and they want to hear from farmers about how their food is produced, processed, and sold … and everything in between.
- Turn up the volume. While there are numerous initiatives to share information with the public, these messages are not resonating with Canadians. The agriculture and food system must turn up the volume, speak with a unified tongue, and engage with Canadians.

Food is Important to Canadians

When provided a list of life issues, the Canadian Centre for Food Integrity's (CCFI) Public Trust Research released in the fall of 2022 shows that Canadians are most concerned about the rising costs of food, followed by inflation and keeping healthy food affordable (Figure 1). In fact, food issues ranked as the top issues — above global warming/climate change and energy costs. With clear majorities expressing concerns over food prices and affordability, the respondents suggest that healthy food might be becoming too expensive for many Canadians.

With food and food production high on the minds of Canadians, and with sustainability and environment always in the headlines, the entire Canadian agriculture and food system has a role to play in providing information that is transparent, trustworthy, and provides assurance to Canadians.

What Information Are Canadians Seeking?

Canadians are seeking a variety of information about food and food production. Interestingly, Canadians are becoming less concerned about intricate details and specific issues like antibiotics and hormones, and more interested in the bigger picture of food production and the agri-food system as a whole. From a trust building perspective, this means there is an opportunity for more simplified messaging that addresses priority issues.

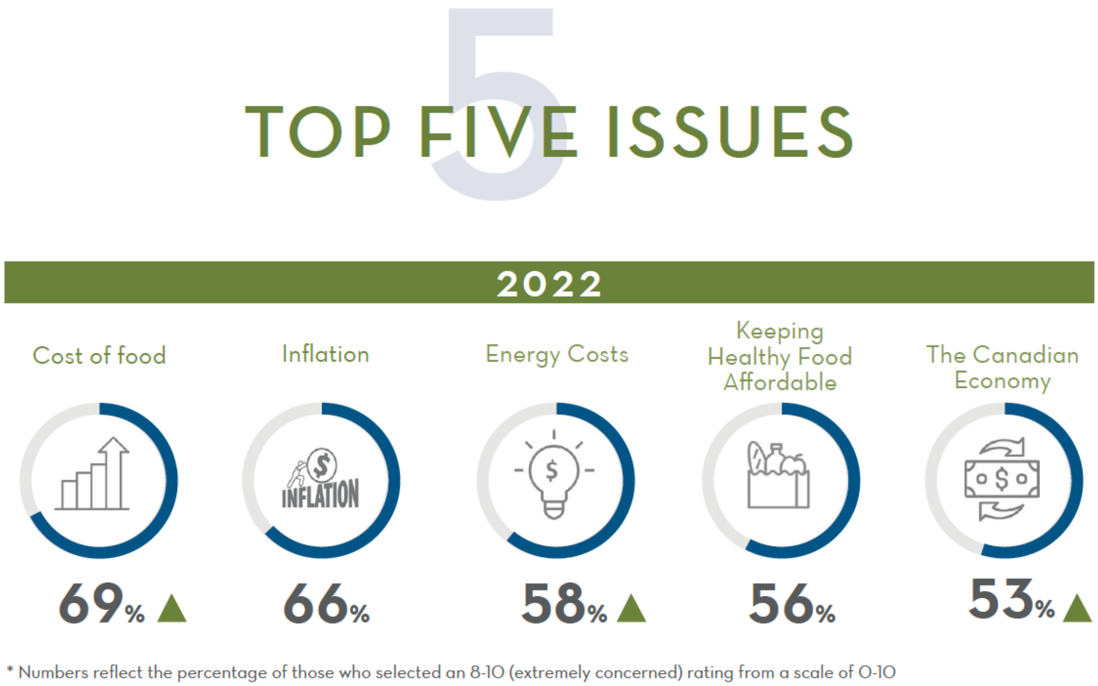

Figure 1. Top five issues as voted by Canadians participating in the 2022 Canadian Centre for Food Integrity's (CCFI) Public Trust Research (https://www.foodintegrity.ca/download-2022-research-report/).

Within the past two years, CCFI research shows that three quarters of Canadians have sought information about a food related topic. Among those who have done this, nutrition and healthy eating are at the top of the 2022 list, although down compared with 2021. Nutrition and healthy eating are followed distantly by locally grown food and food safety. Canadians are also seeking information about humane treatment of animals and plant-based alternatives.

Many Canadians are also concerned about the working conditions of agriculture and food system workers. The overall health and well-being of the worker rank highest, but compensation and safety are also cited. Canadians are watching our actions.

▪ Who Do Canadians Trust?

Although tracking results have remained steady over the years, there are significant decreases in those who trust Canada's agriculture and food system overall (Figure 2). Trust remains strong for farmers. Scientists are also trusted. And politicians continue to be in the basement with government agencies and food processors and manufacturers just slightly above them.

After a significant increase in 2020, there has been a significant drop in the number of Canadians who feel the Canadian food system is headed in the right direction in 2021 and in 2022 (Figure 3). While this isn't good news, it is important to note that the price of food was the major reason for Canadians citing the food system heading in the wrong direction. Again, this points to the importance of communicating with Canadians about the good work that the agriculture and food system is doing every day to produce and deliver abundant, safe, healthy, and affordable food.

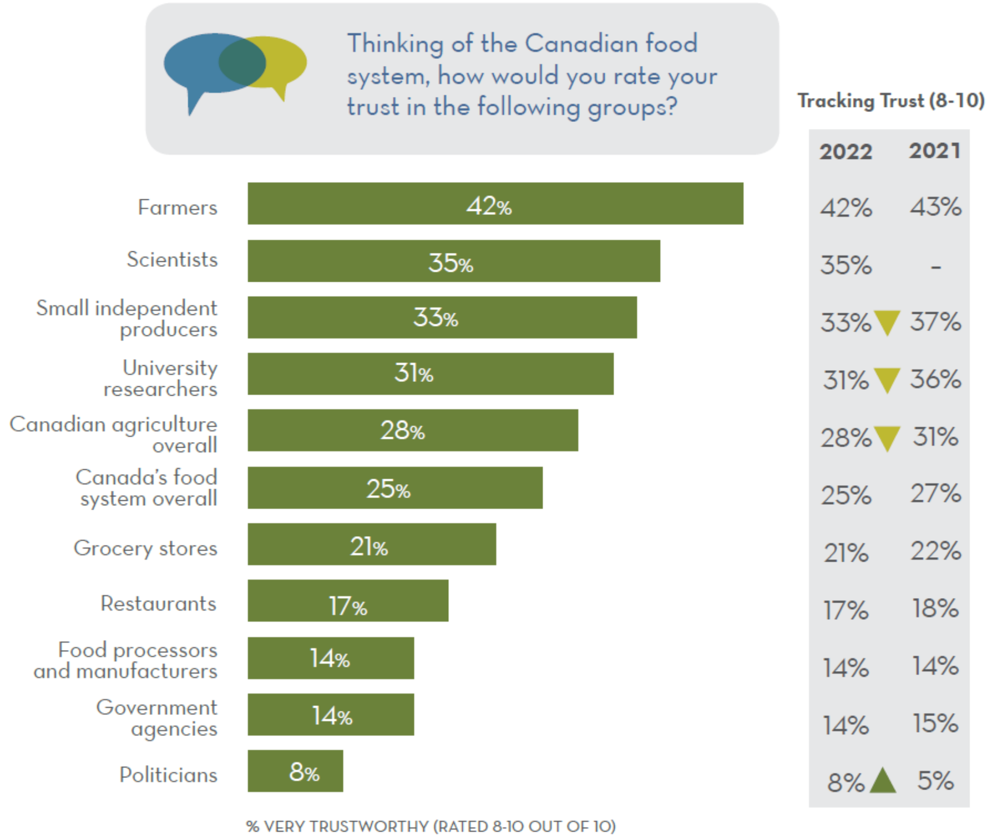

Figure 2. Level of trust in different food organizations as voted by Canadians participating in the 2022 CCFI Public Trust Research (https://www.foodintegrity.ca/download-2022-research-report/).

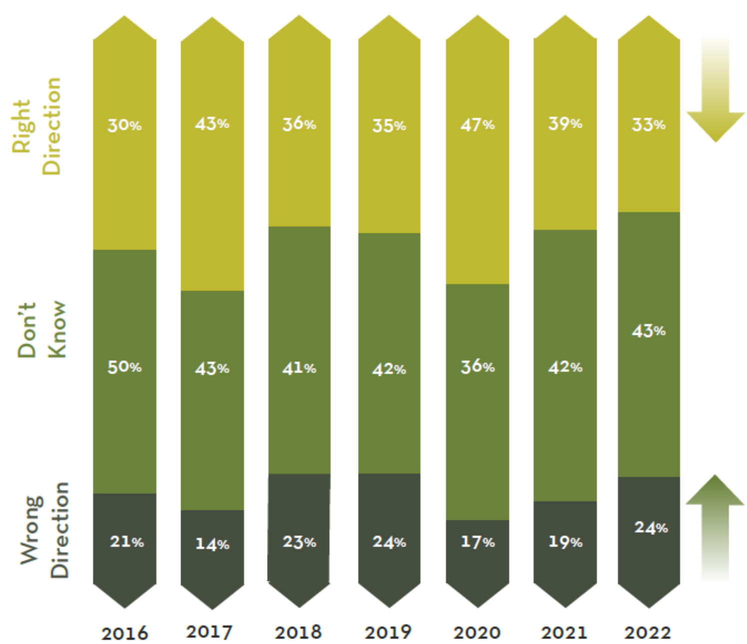

Figure 3. Public sentiment when asked if the Canadian food system is headed in the right direction during CCFI Public Trust research since 2016 (https://www.foodintegrity.ca/download-2022-research-report/).

How Do You Build Public Trust?

“If there is no trust, there is no us!”

For too long the agriculture and food system has not taken maintaining public trust seriously. Every organization, no matter how large or small, requires some level of trust from their stakeholders — customers, employees, the local community, regulators, legislators — and influencers. And every year, the list of influencers seems longer, and the strength of their voice seems to grow in importance.

Building public trust in food and farming is a global issue. Europe is often the region where issues first begin but North Americans are quickly following.

How do you build public trust? Building trust involves an investment and a long-term commitment. It is not just about giving consumers more science, research, and information; it is about demonstrating that we share their values when it comes to topics that matter to them. And as consumer values change, the agriculture and food system needs to evaluate and modify current practices and alter the way it communicates in order to maintain public trust.

The simplistic ‘Trust Framework’ illustration outlines the key components when building public trust (Figure 4):

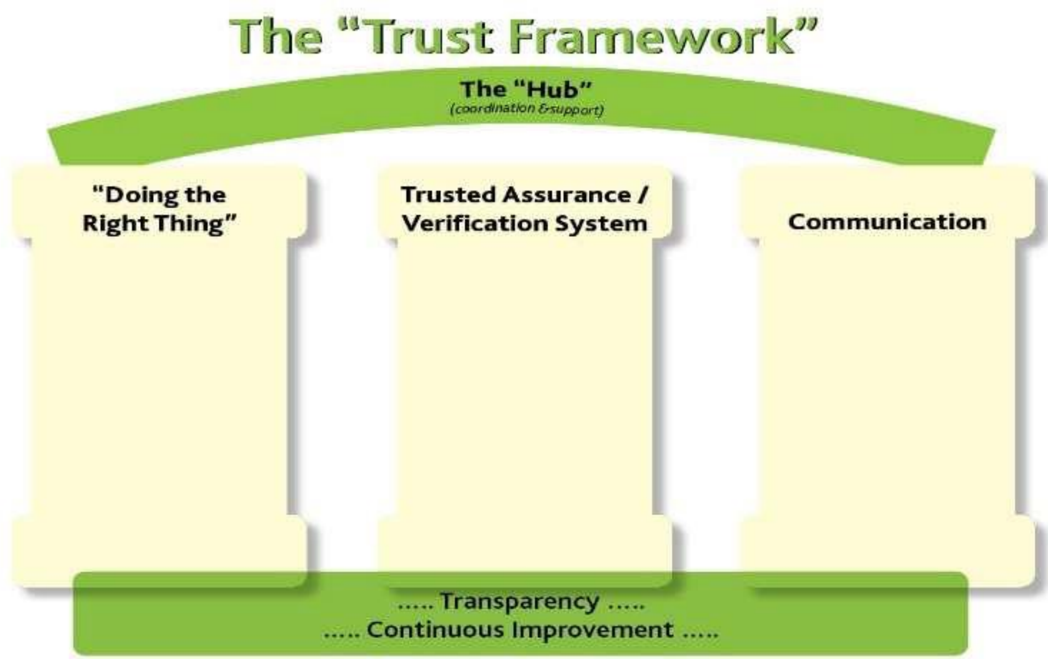

Figure 4. The “Trust Framework” as presented to the Canadian Federation of Agriculture in Public Trust Performance Metrics (https://www.cfa-fca.ca/).

The framework model includes three pillars, a strong foundation, and an umbrella that coordinates. The first pillar involves ‘doing the right thing’; this means an ongoing commitment to follow and document best practices at the farm and throughout the entire agriculture and food system related to production, environment, and social expectations.

The second pillar involves a credible system that can verify that the proper practices are being followed. This can include audits, certification and other assurance systems that provide consumers with a high level of confidence.

The third pillar is communications — meaningful engagement and effective values-based communication presented in a manner that resonates with Canadians.

All three pillars sit on a foundation of transparency and continuous improvement. Transparency is no longer an option in earning trust, and as the adage says, ‘in a world where nothing can be hidden, we better have nothing to hide’. And while most Canadians aren’t expecting perfection, they are expecting continuous improvement. Again, communication is critical in conveying transparency and continuous improvement.

The final component is a collective and coordinated effort to streamline efficiency and effectiveness. Most consumers don’t know the difference between a dairy cow and a beef cow, a wheat field and a pea crop, or a pig barn and a poultry operation; they see a farm and a food system, and they want to know that it is operating properly, delivering safe and healthy food, and has an ongoing commitment to sustainability, people and planet. They also don’t want a bunch of different approaches but rather a food production system that delivers consistency and a commitment to excellence.

Turn up the Volume

Increasingly Canada’s agriculture and food system recognizes the importance of public trust. It knows it needs to take trust development seriously to maintain its ability to operate in a profitable manner that aligns with Canadians’ expectations. It knows that greater efforts are required to provide the information and address the issues that are on the minds of Canadians, and it needs to ‘turn up the volume’ so that consumers gain greater understanding and confidence. We also know that this is a big job and one that requires priority and resources.

This job is best achieved when the agriculture and food industries work together and in harmony. As the saying goes, “if you want to go fast then go alone; but it you want to go far then go together”.

Resources

- The Canadian Centre for Food Integrity website
- https://www.foodintegrity.ca/wp-content/uploads/2022/10/2022-ENG-Public-Trust-Research-Report.pdf


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MORE THAN JUST FEED

Implementation, impacts and economic aspects of selective dry cow therapy and selective treatment of clinical mastitis in Canadian dairy herds

Julia S. Bodaneze[1,2], Kayley D. McCubbin[1,2], Ellen de Jong[1], Karin Orsel[1], Jeroen de Buck[1], David Renaud[3], Caroline Ritter[4], Diego Nobrega[1,2] and Herman W. Barkema[1,2].
[1]Dept. of Production Animal Health, Faculty of Veterinary Medicine, University of Calgary; [2]One Health at UCalgary, University of Calgary; [3]Ontario Veterinary College, University of Guelph; [4]University of Prince Edward Island. E-mail: julia.bodaneze@ucalgary.ca

Project objectives are: 1) assess prevalence of antimicrobial resistance (AMR) in mastitis pathogens in Canadian dairy herds; 2) identify herd- and cow-level criteria for implementing selective dry cow therapy (SDCT) and treatment of clinical mastitis (CM); 3) evaluate impacts of selective DCT and selective treatment of CM on farm-level parameters; 4) determine whether selective DCT or selective CM treatment reduces AMR prevalence in mastitis pathogens; 5) estimate economic impacts of selective practices (DCT and CM treatment) considering Canadian settings; and 6) develop practical standard operating procedures (SOPs) for selective DCT and CM treatment. In order to achieve a representative sample enrollment criterion will include 60 dairy farms with different management practices across Alberta, Quebec, Ontario, and Atlantic Canada. The proposed study will contribute to producer knowledge of their resistance levels, as well as the overall AMR prevalence in the Canadian dairy industry, and assessment of adopted AMU reduction practices. Re-evaluating the AMR prevalence on dairy farms with enacted management changes will greatly contribute to the understanding of effectiveness in AMR mitigation efforts through selective treatment practices. This project will have a major emphasis on knowledge transfer with written reports and producer meetings, as well as provide practical performance-based standard operating protocols that could be adapted to the industry as a whole. Overall, this project will identify best practices related to AMR, improving dairy farm profitability, animal welfare, public health, and consumer confidence.
Take home message: We expect that by using social sciences to facilitate peer-to-peer learning as well as developing standard operating protocols will motivate producers and veterinarians to use antibiotics more prudently. As more countries regulate specific antimicrobial classes, we ultimately hope this self-regulation of AMU will strengthen industry resilience.

Determinants of antimicrobial resistance patterns in bovine mastitis *Streptococcus* isolates from Canadian dairy herds

Ben Caddey, Diego Nobrega, Jeroen de Buck, Herman W. Barkema
Faculty of Veterinary Medicine; AMR – One Health Consortium, University of Calgary, AB, Canada. benjamin.caddey@ucalgary.ca

The emergence and spread of antimicrobial resistance (AMR) is a global burden that threatens animal, human, and environmental health. The development of AMR in livestock production industries produces a serious risk towards our food security. In Canadian dairy herds, intramammary infections causing clinical and subclinical mastitis are the most common reason for antimicrobial use (AMU). *Streptococcus* spp. are among the most important groups of bacteria causing clinical mastitis worldwide, and unnecessary use of critically important antimicrobial drug classes against these pathogens may further the risk of a high AMR prevalence. Therefore, we aim to investigate the molecular epidemiology of *Streptococcus* spp. in Canada, including determining the prevalence and risk factors of AMR. Whole-genome sequencing (WGS) of approximately 1000 bovine mastitis *Streptococcus* isolates from the Mastitis Pathogen Culture Collection of the Canadian Bovine Mastitis and Milk Quality Research Network will provide deep insight into determinant genes and mechanisms of AMR, and allow for phylogenetic analysis for species- and strain-level comparisons. Phenotypic AMR will also be explored by broth microdilution against 20 antimicrobials commonly administered in livestock and human medicine. Risk factors for phenotypic AMR prevalence and multidrug resistance will be explored against AMU rates, route of antimicrobial administration, *Streptococcus* WGS information, and herd-level farm and production parameters. Phenotypic and genotypic analyses are currently being performed.
Take home message: As the dairy industry is pushed towards more stringent antimicrobial stewardship practices, changes to policy regulations and herd management practices must be based on quality research. Correspondingly, the data to be presented from this comprehensive surveillance of *Streptococcus* mastitis isolates will uncover the magnitude of AMR levels across Canada and will provide intense understanding of AMR determinants and risk factors for researchers and dairy industry professionals alike.

Nutritional evaluation of metabolizable protein and degraded protein balance of chickpea varieties growth in western Canada for dairy cows

Linda Cerna, and Peiqiang Yu*
Department of Animal and Poultry Science, College of Agriculture and Bioresources, University of Saskatchewan. *Corresponding author: Email: peiqiang.yu@usask.ca

There is limited information about detailed nutritional value of chickpeas for ruminants. The objectives of this study were to evaluate metabolizable protein and degraded protein balance of chickpeas varieties growth in western Canada for dairy cows. Three chickpea varieties were grown in three locations in western Canada. The items included MCP_{TDN}: rumen synthesized microbial protein base on available TDN; MCP_{RDP}: microbial protein synthesized in the rumen based on available protein, AMCP: truly absorbed microbial protein in the small intestine; ARUP: truly absorbed rumen undegradable protein in the small intestine; AECP: truly absorbed rumen endogenous protein in the small intestine; MP: metabolizable protein, as well as DPB: rumen degraded protein balance. The treatment design was one-way structure and the experimental design was a randomized complete block design with variety as a fix effect and location as a random effect. The data was analyzed using SAS MIXED model procedure. The results showed the variety did not have significant impact on truly absorbed microbial protein in the small intestine (AMCP) with an average of 66 g/kg DM, truly absorbed rumen undegradable protein in the small intestine (ARUP) with an range from 67 of 95 g/kg DM, truly absorbed rumen endogenous protein in the small intestine (AECP) with an average of 4 g/kg DM, metabolizable protein (MP, ranging from 138 to 166 g/kg DM), as well as negative rumen degraded protein balance (DPB, ranging from -41 to -56 g/kg DM).
Take home message: This study indicated that chickpea variety did not show a great impact on true protein value in terms of metabolizable protein and degraded protein balance for dairy cows. The negative degraded protein balance indicated a potential shortage of protein for optimal nitrogen and energy synchronization.

How does the duration of low feed intake affect the ruminant gastrointestinal tract?

K. Lambert[1], A.C. Chagas[1], K. Burakowska[1], D. Watanabe[1], K. Hare[1,2], G.B. Penner[1]
[1]University of Saskatchewan, Saskatoon, SK, S7N 5A2, [2]Univeristy of Guelph, Guelph, ON, N1G 2W1. Koralie.lambert@usask.ca

Cattle experience periods of low feed intake (**LF**) in association with parturition, metabolic disorders, infectious disease, and heat stress. Little is known about how the gastrointestinal tract of ruminants responds to periods of LF. The objective was to determine the impacts of different durations of LF on the gastrointestinal tract (**GIT**) in lambs. Twelve rams and nine wethers were blocked by sex and BW and exposed to 5-d of ad libitum feeding followed by 0 (**CON),** 5 (**LF5**; fed at 30% DMI), or 10 d (**LF10;** fed at 30% DMI) of low feed intake. At the end of the study, lambs were euthanized and the gastrointestinal tract was removed to determine the digesta and tissue weights by region. In addition, the weights of the liver, spleen, and kidneys were recorded. Initial and final BW did not differ by treatment, but the weight of the reticulo-rumen was less for LF10 than CON with LF5 being intermediate but not different. Abomasal tissue weight was lighter for LF10 than CON and intermediate but not different for LF5. Likewise, the abomasal digesta weight was the greatest for CON, intermediate for LF5, and the least for LF10. The weight of the duodenum and ileum tended to be greater for CON than either LF treatment; while, for the jejunum's weight, CON was only greater than LF10. Cecal tissue weight was not affected but digesta weight was the greatest for LF10, intermediate but not different for LF5, and the least for CON. In contrast, colonic tissue weight was least for LF10 relative to LF5 and CON and digesta weight was greater for CON than either LF treatment. Liver weight was reduced for both LF5 and LF10 relative to CON, but kidney and spleen weights were not affected.
Take-home message: Exposure of ruminants to LF may reduce the weights of the gastrointestinal tract regions and liver with rapid effects. These changes likely reflect reduced absorptive capacity of the gastrointestinal tract and lesser metabolic capacity of the liver.

Optimizing GnRH-based protocols for timed-AI in Holstein heifers

M.G. Colazo[1], R.J. Mapletoft[2], A. Behrouzi[1]
[1]University of Alberta; [2]University of Saskatchewan; E-mail: colazo@ualberta.ca

Holstein heifers (n=334) were fitted with a collar-mounted automated activity monitoring system (SCR) at ~13.5 mo of age and assigned randomly to one of three different timed-AI (TAI) protocols. Heifers in the G100 group received a standard 5-d CO-Synch protocol [100µg of gonadorelin (GnRH) on Day 0 and 500 µg of cloprostenol (PG) on Days 5 and 6] plus a progesterone device (PRID ® DELTA) between Day 0 and 5. Heifers in the G200 group received similar treatments as G100 except the GnRH dose on Day 0 was of 200 µg. Heifers in the P10 group received a PRID and PG on Day -5, 100µg of GnRH on Day 0, PRID removal on Day 5 and PG treatments on Days 5 and 6. All heifers were TAI ~72 h after PRID removal and concurrently GnRH was administered to those not exhibiting estrus. Inseminations were done by one technician using either sex-sorted (n=265) or conventional (n=69) frozen-thawed semen. Estrus events were recorded and transrectal ultrasonography was done to monitor ovarian dynamics and determine pregnancy per AI (P/AI). All heifers were cycling and ovulatory response to initial GnRH was greater (P<0.01) in G200 (51.8%) and P10 (47.7%) compared to G100 (27.9%). Estrus rate tended to be greater (P=0.08) in G100 (93.7%) compared to G200 (85.7%) and intermediate in P10 (89.2%). Expression of estrus was positively associated with P/AI at 45 d post TAI (P<0.01; 70.2 vs. 31.4% for those expressing or not estrus). G200 heifers had greater (P<0.05) P/AI at 28 and 45 d post TAI (79.5 and 75.9%) compared to that in G100 (63.1 and 60.4%) and P10 (64.0 and 62.2%) heifers. Pregnancy loss did not differ among treatments (overall 3.9%).

Take home message: Inconsistent results have been reported in heifers subjected to GnRH-based protocols and poor ovulatory response to initial GnRH has been identified by our research as one of the leading factors explaining those results. Findings from the current study suggest that increasing the dose of initial GnRH from 100 to 200 µg resulted in increased ovulatory response and improved P/AI.

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Comparison of two intravaginal progesterone-releasing devices in Holstein cows synchronized with a 5-d GnRH-based TAI protocol: preliminary results

M.G. Colazo[1], R.J. Mapletoft[2], A. Behrouzi[1]
[1]University of Alberta; [2]University of Saskatchewan; E-mail: colazo@ualberta.ca

Holstein cows fitted with a collar-mounted automated activity monitoring system (Alta Cow Watch) that were either non-cycling after the voluntary waiting period or non-pregnant and non-returning to estrus following AI were enrolled. Cows were subjected to a standard 5-d CO-Synch protocol [100µg of gonadorelin (GnRH) on Day 0 and 500 µg of cloprostenol on Days 5 and 6] and allocated randomly to receive either a progesterone device containing 1.35 g (CIDR; n=220) or 1.55 g (PRID ® DELTA; n=223) of progesterone between Day 0 and 5. All cows received a second administration of GnRH approximately 56 h and timed-AI (TAI) 72 h after device removal. Inseminations were done by one technician using conventional frozen-thawed semen. Estrus events were recorded and transrectal ultrasonography was done on Day 0 to determine cyclicity and 32 and 60 d post-TAI to diagnose pregnancy. Cows had an average of 2.2 lactations, 123 days in milk and milk yield of 44.4 kg/d at enrollment. The percentage of cyclic cows was 60.9% and did not differ between treatments. Expression of estrus prior to TAI did not differ between treatments, but affected P/AI at 32 and 60 d post-TAI (P<0.01; 54.0 and 49.6% vs. 35.4 and 31.2% for those expressing or not estrus, respectively). Cyclic cows had greater P/AI at 32 and 60 d post-TAI than acyclic cows (P<0.01; 44.8 and 40.7% vs. 32.9 and 28.3%). Pregnancy per AI at 32 d did not differ between treatments (P=0.7; 39.5 vs. 40.8% for CIDR and PRID groups). However, P/AI at 60 d tended (P=0.1) to be greater in PRID-treated cows (38.6%) compared to CIDR-treated cows (33.2%). Thus, PRID-treated cows had lower pregnancy lost than PRID-treated cows (P=0.048; 5.5 vs. 16.1%).

Take Home Message: PRID-treated cows had lower pregnancy lost than CIDR-treated cows. Estrus expression prior to TAI was poor regardless of treatment, but positively associated with P/AI. Future studies should investigate strategies to increase the expression of estrus prior to TAI in cows.

*Authors thank Breevliet Ltd

Factors associated with estrus expression determined by an activity monitoring system in dairy cows administered prostaglandin F2α

M.G. Colazo[1], A. Behrouzi[1], M. Gobikrushanth[2],
[1]University of Alberta; [2]University of Queensland; E-mail: colazo@ualberta.ca

A total of 423 Holstein cows fitted with a collar-mounted automated activity monitoring (AAM) system (Alta Cow Watch) were included. Cows were administered 500 µg of cloprostenol (PG); cows that did not express estrus after first PG received a second PG 14 d apart. All cows were cyclic (presence of a CL determined by ultrasonography) and the average daily milk yield and days in milk at PG treatment were 44.0 ± 0.34 kg and 69.8 ± 0.42 d, respectively. Estrus events were alerted by the AAM system after the activity threshold (recommended by the manufacturer) was reached. A total of 655 doses of PG were administered. The number of cows expressing estrus following first and second PG administration was 191 and 82, respectively. Overall, 64.5% of cows expressed estrus and the expression of estrus was associated with lactation number, incidence of mastitis at the time of PG treatment and number of estrus events prior to PG administration. First lactation cows had lower estrus expression than second or third and greater lactation cows (P=0.01; 55.4, 67.7 and 71.9%, respectively). Cows with mastitis at the time of PG administration had lower expression of estrus compared to healthy cows (P=0.03; 53.4 vs. 66.3%). The percentage of cows with at least 1 estrus event prior to PG treatment was 46.1%. Cows with 1 or ≥ 2 (91.0%) previous estrus events were more likely (P<0.01) to express estrus following PG treatment compared to cows with no previous estrus event (80.5, 91.0 and 47.8%, respectively). However, estrus expression was not associated with incidence of diseases during transition (P=0.25), average daily milk yield (P=0.58) and season (P=0.30) at the time of PG administration.
Take Home Message: Approximately one third of the cows were not alerted in estrus by the AAM system following PG administration. Cows during first lactation, cows with mastitis and those with no previous estrus event before PG treatment were less likely to be identified in estrus by the AAM system.
*Authors thank Breevliet Ltd

Evaluating the optimum timing of insemination in dairy cows identified in estrus by an activity monitoring system

M.G. Colazo[1], A. Behrouzi[1], M. Gobikrushanth[2],
[1]University of Alberta; [2]University of Queensland; E-mail: colazo@ualberta.ca

A total of 708 estrus events from Holstein cows fitted with a collar-mounted automated activity monitoring (AAM) system (Alta Cow Watch) were analyzed. An estrus event was identified by the AAM system after the activity threshold was reached. Estrus events were categorized as spontaneous (n=471) or induced (n=237) after prostaglandin F2α treatment. Length (LE), onset (OE) and end of estrus (EE) events were recorded. Inseminations were done using conventional frozen-thawed semen and the time of insemination was recorded. Pregnancy diagnosis was done by transrectal ultrasonography 32-37 d post-AI. Pregnancy per AI (P/AI) and LE did not differ between spontaneous and induced estrus events, so data were combined for further analyses. LE was longer (P=0.04) in second lactation cows compared to first or third and greater lactation cows (9.1, 8.4 and 8.3 h). P/AI was greater (P=0.05) in first lactation cows than third and greater lactation cows (52.1 vs. 42.6%), but did not differ (P=0.3) from second lactation cows (46.2%). The range for the interval from OE to AI and EE to AI was 5 to 36 and -10 to 35 h, respectively. The relationship between the interval from OE to AI and predicted probability of pregnancy (PPP) was not significant. However, when the interval from OE to AI increased, numerically PPP decreased in first and second lactation cows (0.54 to 0.44), but increased in third and greater lactation cows (0.40 to 0.50). There was a quadratic effect (P=0.06) of the interval from EE to AI on PPP for first and second lactation cows; inseminations done -3 to 5 h in relation to EE resulted in the greatest PPP (0.52), however, inseminations done > 18 h after EE resulted in PPP < 0.40.
Take Home Message: The optimum timing of AI relative to the onset of estrus was not well-defined, however, data suggest that optimal AI timing could differ according to the number of lactations. The interval from the end of estrus to AI could be a better indicator of the optimal AI timing and warrant further investigation.
*Authors thank Breevliet Ltd

The effect of high or low concentration of progesterone during diestrus and its association with intensity of oestrus in lactating Holstein cattle

R.S. Conceicao[1], A.M.L. Madureira[2], J.C.S. Marques[1], J. Patu[1], A.M. Bega[1], S. Moore[1], C.F. Baes[3], R.L.A. Cerri[1]
[1]University of British Columbia, Faculty of Land and Food Systems, Canada; [2]University of Guelph, Ridgetown Campus, Canada; [3]University of Guelph, Centre of Genetic Improvement of Livestock, Canada. E-mail: rckrebs@student.ubc.ca

The objective of this study was to determine the effect of different concentrations of progesterone (P4) during the oestrus cycle on the intensity of oestrous expression detected by an automated activity monitor (AAM). All cows were enrolled onto a presynchronization protocol, starting on day -27 relative to the final estrus, composed of the administration of GnRH and a P4 insert, 7 d later an injection of PGF2α and insert removal, and a second injection of GnRH 48h later. Cows were then submitted to the same hormonal protocol as the presynchronization program starting on d 7 of the estrous cycle and received an injection of estradiol cypionate (E.C.P) on -2 d of the study. Cows in the high P4 (HP; n = 61) treatment received no additional treatment. Cows in the low P4 (LP; n = 64) treatment received extra PGF2α injections on day – 15, - 14.5, and 14 and again on day – 10, - 9, -8.5, and – 3 of the protocol. Blood samples were harvested to quantify the concentration of P4 throughout the study. Individual activity was monitored continuously by a leg mounted AAM. Concentration of P4 was greater for HP cows on day – 8 and – 3 of the study, as expected. At the time of the estrus alert, cows on the HP treatment had lower P4 concentration compared with cows on the LP (0.78 ± 0.14 ng/mL vs. 1.36 ± 0.11 ng/mL, respectively). The proportion of cows that did not show oestrus was greater for HP than for LP (18.2 % vs. 5.1%), however, cows in the HP treatment had greater relative increase in activity compared with cows on the LP treatment (398.5 ± 21.1 RI vs. 312.4 ± 19.8 RI, respectively).
Take home message: There was no difference in the duration of oestrus. In conclusion, cows enrolled the HP treatment had fewer cows expressing oestrus, however they had greater concentration of P4 during diestrus and had greater relative increase at oestrus compared with cows that were enrolled in the LP treatment.

The effect of high or low concentration of progesterone during diestrus and its association with the LH surge and PGF2α metabolite in lactating Holstein cattle

R.S. Conceicao[1], A.M.L. Madureira[2], J.C.S. Marques[1], J. Patu[1], A.M. Bega[1], S. Moore[1], C.F. Baes[3], R.L.A. Cerri[1]
[1]University of British Columbia, Faculty of Land and Food Systems, Canada; [2]University of Guelph, Ridgetown Campus, Canada; [3]University of Guelph, Centre of Genetic Improvement of Livestock, Canada. E-mail: rckrebs@student.ubc.ca

The objective of this study was to determine the effect of progesterone concentration during the oestrus cycle on circulating LH and PGFM. Cows were enrolled into a presynchronization protocol, starting on day -27, composed of the administration of GnRH and a P4 insert, 7 d later an injection of PGF2α and insert removal, and a second injection of GnRH 48h later. All cows were then resubmitted to the identical presynchronization program again, starting on d 7 of the oestrous cycle and received an injection of estradiol cypionate (E.C.P) on -2 d. Cows in the high P4 (HP; n = 8) treatment received no additional treatment. Cows in the low P4 (LP; n = 9) treatment received extra PGF2α injections on days -15, -14.5, -14, -10, -9, -8.5, and -3. Blood samples were collected, to quantify the peak LH concentration after E.C.P. administration, every 2 hours until ovulation. Ovulation was confirmed by transrectal ultrasonography. An estradiol/oxytocin challenge for PGFM was performed on day 16 of the treatment. E.C.P (0.5 mL) was administrated 4 h before the intravenous treatment of oxytocin (5 mL). Blood samples were collected at -15, 0, 15, 30, 45, 60, 90, 120, and 180 min relative to the oxytocin injection. Concentration of LH tended to be lower for HP than LP cows (0.49 vs. 0.58 ng/mL). Duration from E.C.P. administration to peak LH was longer for cows in the HP treatment compared with the LP treatment (37.3 ± 6.3 h vs. 28.3 ± 4.8 h). The duration of the LH peak was greater in the LP treatment compared with the HP treatment (8.7 ± 1.0 h vs. 6.3 ± 1.6 h). The duration from peak LH to ovulation was shorter in the LP treatment compared with the HP treatment (26.4 ± 2.3 h vs. 35.1 ± 5.7 h). Concentrations of PGFM were greater for the LP treatment than the HP treatment (107.8 pg/mL vs 92.5 pg/mL).
Take home message: Cows that were exposed to lower concentrations of P4 during diestrus tended to have greater LH concentrations and greater circulating concentrations of PGFM following an oxytocin challenge in the subsequent oestrous cycle.

Associations between personality traits of dairy cows and their heifer offspring

S. C. Czachor, A. J. Schwanke, J. E. Brasier, B. J. Van Soest, and T. J. DeVries
Department of Animal Biosciences, University of Guelph, tdevries@uoguelph.ca

Personality traits of dairy cattle affect behavior and production, but it is not well known how heritable these traits may be. The objective of this study was to determine the correlation between personality traits of dairy cows and their heifer offspring. Twenty-three Holstein dairy cows had their personality traits assessed at 24 d prior to calving and 24 d after calving, and their offspring were assessed at 7 months of age. Personality traits of all animals were assessed through observation of behaviours in response to a novel environment, object, and human. Principal components analyses identified the traits of active, exploratory and bold in the pre-partum test conducted on dams (76% cumulative variance), and the traits of active and exploratory in the post-partum test (79% cumulative variance). Cow scores within the active and exploratory traits between these 2 tests were consistent (P<0.01, R^2=0.35 and P=0.02, R^2=0.10 respectively). From personality assessment in heifers, principal components analysis resulted in 3 traits from the novel object test (bold, exploratory-active, and social; 81% cumulative variance), and 2 traits from the novel human test (exploratory-active and social; 74% cumulative variance). Cows who were more exploratory pre-partum were associated with having heifers that were less bold in the novel object test (P=0.01, R^2=0.26). Cows who were more active pre-partum tended to be associated with heifers who were more exploratory-active in the novel object test (P=0.06, R^2=0.16), while cows who were more active post-partum tended to be associated with heifers that were more bold in the novel object test (P=0.07, R^2=0.15).
Take home message: The data from this study indicates that there are some associations between the personality traits of cows and heifer offspring, which with further investigation may allow prediction of heifer personality and better inform young stock management.

Effects of weaning and tyndallized *Lactobacillus helveticus* supplementation on dairy calf behavioral and physiological indicators of affective state

B. K. McNeil[1], D. L. Renaud[2], M. A. Steele[1], L. R. Cangiano[1], M. F. Olmeda[1], and T. J. DeVries[1]
[1]Department of Animal Biosciences, University of Guelph, Guelph, ON, N1G 2W1, Canada; [2]Department of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, ON, N1G 2W1, Canada. bmcnei01@uoguelph.ca, tdevries@uoguelph.ca

The objectives of this study were to determine if weaning of dairy calves would induce behavioral and physiological indicators of a negative affective state, and if tyndallized *Lactobacillus helveticus* (TLH) supplementation would reduce those indicators of negative affect during weaning. Male Holstein calves (n=23) were enrolled in the 42 d study. Calves began weaning from 9 L/d of milk replacer (MR) on d 35 and received 6 L/d on d 35–36, 3 L/d on d 37–38, and 0.4 L/d on d 39-42, fed at 150 g of MR powder/L. Within room, calves were assigned to 1 of 2 treatments: 1) control (CON; n=11) and 2) 5 g/d of TLH split over and mixed into 2 daily MR feedings from d 3-42 (TLH; n=12). Lying behavior was tracked from d 21-41. On d 33, 37, and 41, infrared eye images were taken to determine maximum eye temperature (MET), saliva samples were collected to determine cortisol concentration, and play assessments were done. On d 34, 38, and 42, blood samples were collected to determine blood serotonin concentration. On d 38 and 39, calves were tested with a cognitive task. Weaning resulted in fewer, but longer, lying bouts ($P\leq0.001$) and reduced play behaviour ($P\leq0.001$). No changes in lying time ($P=0.13$), MET ($P=0.76$), saliva cortisol ($P=0.75$), nor blood serotonin ($P=0.60$) were detected with initiation of weaning. TLH supplementation was associated with lower lying time throughout ($P\leq0.09$), and reduced play duration ($P=0.04$) and higher salivary cortisol ($P=0.01$) and MET ($P=0.08$) during weaning. Only CON calves completed the cognitive task faster on d 39 ($P=0.04$). No treatment differences in lying bouts ($P\geq0.44$) or blood serotonin ($P\geq0.26$) were detected throughout.
Take home message: Weaning appeared to induce negative affect, while the results of TLH supplementation on reducing those negative effects are inconclusive.

Identifying reservoirs of bacteria involved in digital dermatitis in dairy cows and farms with different disease status

Angelica Dias[1*], Karin Orsel[1], Jeroen De Buck[1; 1]Faculty of Veterinary Medicine, University of Calgary, AB, Canada.
Email: *angelica.petersendias@ucalgary.ca

Despite ongoing investigations, the source of infection and routes of transmission of digital dermatitis (DD), a polybacterial hoof disease, are still under debate. Recent progress in molecular techniques now enables a more in-depth investigation of the bacteria most associated with DD and what their reservoirs are in cattle and the environment. This study aimed to investigate the presence and quantity of DD-associated bacteria in dairy cattle hoof skin, saliva, urine, feces, and slurry. Environmental samples were collected from the free-stall barns, and swabs of lesion or healthy hoof skin were taken from 103 milking cows in addition to saliva, urine, and feces. Animals were classified as DD-free (M0, n=58), with active (M2, n=16) or chronic lesions (M4, n=29). Farms were categorized as free (DD-free, n=2), with only chronic lesions (M4-only, n=2), and with active/chronic lesions (M2/M4, n=2). On DD-free farms, treponemes were only found in saliva, while on M2/M4 and M4-only farms, they were present in saliva, healthy hoof skin, and in slurry. All fecal and urine samples were negative; thus, the presence of treponemes in the slurry suggests transient contamination from active and chronic lesions. Non-treponeme anaerobes were absent in feces but present in urine, healthy hoof skin, saliva, and slurry regardless of disease status. Unlike treponemes, the other anaerobes seem to be ubiquitous, suggesting they are secondary pathogens. Transmission is unlikely through feces and urine as those sources do not seem to be reservoirs for bacteria involved in DD, whereas saliva may serve as a potential reservoir; however, longitudinal follow-up studies are needed to support bacterial shedding and sites of persistence.
Take home message: Insights from this study on potential reservoirs of bacteria involved in DD will guide future investigations focusing on management practices to minimize or eliminate bacterial excretion and DD transmission.

Clearance of a genetically modified *Mycobacterium avium subsp. paratuberculosis* strains from calf tissue and partial protection against infection

Razieh Eshraghisamani[1], Jeroen De Buck[1].
[1]Faculty of Veterinary Medicine, University of Calgary, Calgary, Alberta, Canada. Emails: razieh.eshraghisaman@ucalgary.ca, jdebuck@ucalgary.ca

Commercially available Johne's disease vaccines reduce *Mycobacterium avium* subsp. *paratuberculosis* (MAP) fecal shedding and postpone the clinical symptoms without eliminating the infection and its spread. Our study aimed to develop a vaccine that overcomes the shortcomings of previous vaccines. Essential genes for MAP survival in the host's body were identified. Two essential genes, which play roles in iron acquisition (*BacA*) and fatty acid metabolism (*IcL*), were chosen to be knocked out of MAP genome. To evaluate the persistence of modified strains in tissue and the protection against infection, two calf infection trials were conducted. Twenty-three calves were randomized over four groups including *BacA*, *IcL*, uninfected and wild-type (WT) controls. Calves were inoculated with 10^9 CFU of each MAP strains at two weeks old. Blood samples were collected every two weeks to study immune responses. Tissue samples were collected 4 months after inoculation. Both modified strains were cleared from tissue without losing their immunogenicity. By inducing stronger immune responses, only *BacA* showed potential capability to protect animals against infection and proceeded to calf challenge trial. Next, a calf challenge trial was conducted to evaluate the efficacy of preventing MAP infection by vaccinating with the *BacA* strain. Twenty-four calves were randomized over four groups including uninfected control, vaccinated, vaccinated/challenged, and infected control. Vaccinated groups got inoculated with 10^9 CFU of *BacA* strain at 2 weeks old. Challenged groups got inoculated with 2×10^9 CFU of MAP at 5 weeks old. Tissue samples were collected 4 months after inoculation. The *BacA* strain could only partially reduce MAP persistence in intestinal tissue.
Take home message: Studying MAP vaccine candidates is a significant step in progressing towards a better JD control. This newly developed live attenuated vaccine partially protected animals against MAP infection.

Bovine mastitis and *S. chromogenes*; concerns, conundrums, and characteristics

Mohamed Ghanduri
Faculty of Veterinary Medicine, University of Calgary, Calgary, AB. Email: ghanduri@ucalgary.ca

An important cause of mastitis are minor pathogens such as non-aureus staphylococci (NAS), which are the most commonly isolated bacteria from milk samples of dairy cows. The most common NAS species globally and especially in Canada, is *Staphylococcus chromogenes*. To understand why *S. chromogenes* is so common we need to study how it interacts with the cow's immune system. We can do that by analysing its genetic code, which gives it the instructions to make proteins that interact with the cow immune system. By genetic comparisons between *S. chromogenes* strains and close NAS relatives, we can narrow down several *S. chromogenes* specific virulence factors. These factors might explain the more persistent and seemingly adapted propensities of *S. chromogenes* in bovine mammary glands. Several of these virulence factors are related to binding and immune avoidance mechanisms. We will test these virulence factors in experimental assays such as biofilm tests, tissue component binding tests, and blood cell assays. Next, we will remove these virulence factors in deletion mutant and observe how they perform in these experimental assays. Genetic manipulation of *S. chromogenes* is notoriously difficult but we have developed a successful method. Further research in dissecting the underlying mechanisms of *S. chromogenes* virulence factors will be essential to understand the overlying host-pathogen mechanisms of mastitis and recognizing some virulence factors essential to *S. chromogenes*, and others potentially important for all NAS. Such research will focus on the particular interactions virulence factors have with the epithelial cells of the bovine mammary gland, as well as the mechanisms involved in avoiding white blood cells by *S. chromogenes*.
Take home message: This research will be essential to scrutinizing the significant virulence factors involved in the bovine mammary gland adapted *S. chromogenes*. By identifying the virulence factors involved, we can begin to break down the adhesion, persistence, and host avoidance mechanisms involved and come up with a solution to lower the impacts of bovine mastitis.

Evaluation of calves testing strategy to support Johne's disease control programs and early disease detection assays

Ana Caroline Pereira[1,2], Karin Orsel[1], Jeroen De Buck[1], Herman W. Barkema[1]
[1]Department of Production Animal Health, Faculty of Veterinary Medicine, University of Calgary. anacaroline.pereira@ucalgary.ca

The lack of testing strategies in dairy calves can partially explain unsuccessful eradication worldwide of *Mycobacterium avium* subsp. *paratuberculosis* (MAP) in dairy herds. The current diagnostic tests to detect MAP infection are less sensitive in the earlier stages of MAP infection. We propose to evaluate the effects of testing dairy calves on within-herd MAP prevalence as part of a new JD control program. First, testing and control measures to develop the inclusion of calves in the testing strategy. The second objective is to evaluate the sensitivity and specificity of fecal qPCR for the gene ISMAP02, ELISA, and interferon-gamma assay (IGRA) in naturally MAP-infected calves. Therefore, the implementation to follow calves naturally infected with MAP over time, considering field conditions, would provide a better evaluation of the applicability of the IGRA. Considering IGRA an indirect marker for MAP exposure, it would be possible to measure the likelihood of latent infection becoming an active infection based on IGRA, which will support early decisions of suspected MAP-positive calves on the farm. Eight dairy farms were selected based on the presence of MAP-positive environmental samples. We will be testing animals <12 mo of age using ELISA and fecal qPCR as reference tests and IGRA every two months, and twice a year whole-herd sampling using fecal qPCR and ELISA on animals >12 mo of age. The results will apply to dairy farms worldwide and provide a better understanding of MAP transmission between calves.
Take home message: IGRA might be a potential indirect marker for MAP exposure to detect latent infection in calves. IGRA testing of blood samples will be at least 10% more sensitive and specific in detecting early immune response in MAP-positive calves than ELISA and direct qPCR from feces.

Effects of processing severity for reconstituted high moisture barley with variable kernel size on ensiling characteristics and in vitro ruminal fermentation

B. Lynch, T. Mutsvangwa, G.O. Ribeiro and G.B. Penner.
University of Saskatchewan, Saskatoon, SK S7N 5A8. Bal523@usask.ca

The objective was to evaluate how processing severity for reconstituted high moisture barley (**RHB**) affects ensiling characteristics and in vitro ruminal fermentation. Three sources of light (605 g/L) and heavy (684 g/L) barley were blended to create four lots of variable kernel sized barley (646 g/L). Barley was then dry rolled (**DR**) to a processing index (**PI**) of 75% or used to produce RHB. For RHB, water was added to achieve 65% DM followed by tempering for 24 h. Thereafter, RHB was rolled to achieve PI values of 65% (RHB65), 75% (RHB75), or 85% (RHB85). The RHB was packed into miniature silos (density 2.15 kg/L) and allowed to ensile for 1 or 5 mo. The RHB ensiled for 1 mo and the DR barley were used to evaluate in vitro ruminal fermentation using the rumen simulation technique. The RHB had greater kernel width prior to rolling and increased kernel length, width, and thickness following rolling than DR. Decreasing the PI from 85 to 75 and 65% for RHB progressively increased kernel thickness. The percentage of fine particles (<1.18 mm) was greater for DR than RHB. The severity of RHB processing did not affect post-ensiling pH, but lactic acid concentration was greater after 5 than 1 mo. The 7-h starch digestibility was greater for 5-mo than 1-mo ensiling and was increased with decreasing PI. Dry matter and organic matter disappearance were greatest for DR and RHB65, intermediate for RHB75, and least for RHB85. Fermenter pH was least for DR, greatest for RHB75 and RHB85, with RHB65 being intermediate but not different from other treatments. Methane production was greatest for DR, least for RHB75 and RHB85, and intermediate but not different for RHB65. Total microbial nitrogen flow was greatest for DR, intermediate for RHB65 and RHB75, and least for RHB85.
Take Home Message: Relative to DR, use of moisture in RHB to swell kernels and prevent shattering during processing may be used to prevent a decline in pH but yield similar digestibility suggesting lesser risk for ruminal acidosis.

Processing induced change in feed milk value of oat grain in comparison with common barley grain for lactating dairy cows: Effect of technological treatments

Marcela R. Tosta, Luciana L. Prates, María E. Rodríguez Espinosa, Peiqiang Yu*
Department of Animal and Poultry Science, College of Agriculture and Bioresources, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5A8, Canada. *Corresponding author: Professor & Ministry of Agriculture Strategic Research Chair; Tel: +1 (306)-966-4132; peiqiang.yu@usask.ca

This study aimed to evaluate the effect of technological processing methods on changes in feed milk value of oat grain for lactating dairy cows in comparison with common rolled barley grain. The processing methods used in this study included pelleting, steam-flaking, and rolling, which were carried out at Canada Feed Research Center (CFRC, SK, Canada). The experimental design was a completely randomized design (CRD) with one way treatment structure. The data were analyzed with the MIXED procedure of SAS 9.4 using the CRD model with processing method as the fixed effect. The feed milk value was evaluated based on total truly absorbable protein value which were contributed from truly absorbable microbial protein, truly absorbable rumen undegraded protein, and endogenous protein. The results showed that the feed milk value significantly differed between oat and barley grain. The rolled barley grain was relatively higher in feed milk feed than that in average of oat grain treatments. Among oat processing treatments, the steam-flaking processing resulted a numerically higher feed milk value than rolling and pelleting (1.36 vs. 1.21 and 1.27 kg milk /kg feed, respectively).
Take home message: This result indicated that the different processing methods may have different impact on feed milk value of grain. It is important to choose a right processing method for different types of grain.

Investigating the importance of subclinical ketosis in robotic milking systems

S. M. Moore, R. Conceicao, J. Marques, J. Denis-Robichaud, R. Cerri
University of British Columbia, Department of Land and Food Science, Vancouver, B.C, Canada; smoore12@mail.ubc.ca

The use of robotic milking systems is increasing worldwide. While many studies have shown pros to these systems, the amount of data collected by these machines is overwhelming to the producer and often ignored. As cows are free in these systems to milk more often, they are producing higher quantities of milk, and the increase in energy required to support this production level has been linked to an increase in prevalent illnesses, such as subclinical ketosis (SCK). The objectives of this study were to describe SCK in robotic milking herds, and to explore factors associated with SCK. A total of 430 cows across 2 commercial robotic milking herds in the Fraser Valley of British Columbia were enrolled in this study 1 week prior to dry off and followed until 60 DIM of the next lactation. Blood samples were collected from the time of dry off, weekly through the prepartum period, the day of calving till 4 days in milk (DIM), then every other day until 14 DIM, and a final sample at 21 DIM. Blood was analyzed cow-side for beta-hydroxy butyrate (BHB) and glucose and sent off for analysis for non-esterified fatty acids (NEFA). As this project is still ongoing, only preliminary results are available. SCK was defined as BHB ≥ 1.2 mmol/L and was diagnosed 426 times among 142 cows in both farms. Of the cows diagnosed with SCK, 63% had 2 or more SKC events. The prevalence of SCK varied across DIM, with the highest prevalence occurring at 8 DIM (21%). Additionally, cows with a body condition score of 3.5 or greater in the dry period were 1.4 times (95% CI = 0.55-1.88) more likely to experience SCK. Cows in the 7th lactation had the highest odds of experiencing SCK (1.9 times more likely than primiparous, (95% CI = 0.99-2.85). Cows with longer dry periods (>62 days) were 3.0 times (95% CI = 2.2-4.1) more likely to experience SCK compared with cows with a dry period of 51 days or less. Future objectives will investigate SCK incidence and the relationship with sensory data (rumination, eating time, milk production, milk frequency, etc.) to determine if new blood thresholds for SCK within robotically milked herds need to be defined.
Take home message: This research aims to re-examine how we diagnose and detect SCK within robotic herds.

Nutritional evaluation of energy value, total digestible nutrients and feed milk value of chickpea varieties growth in western Canada for dairy cows

Linda Cerna, and Peiqiang Yu*
Department of Animal and Poultry Science, College of Agriculture and Bioresources, University of Saskatchewan. *Corresponding author: Email: peiqiang.yu@usask.ca

There is limited information about detailed nutritional value of chickpeas for ruminants. The objectives of this study were to evaluate metabolizable and net energy values, total digestible nutrients, and feed milk value of chickpeas varieties growth in western Canada for dairy cows. Three chickpea varieties were grown in three locations in western Canada. The truly digestible neutral detergent fibre, crude protein, fatty acid, and non-fibre carbohydrate as well as total digestible nutrients were determined and the energy values including digestible energy, metabolizable energy and net energy were determined using the NRC-summary approach. The feed milk value was determined based net energy for lactating dairy cow. The treatment design was one-way structure and the experimental design was a randomized complete block design with variety as a fix effect and location as a random effect. The data was analyzed using SAS MIXED model procedure. The results showed that the total digestible nutrients of chickpea varieties ranged from 86.7 % DM to 87.2% DM. The average metabolizable every of chickpea varieties ranged from 3.2 to 3.3 MCal/kg. The net energy for lactation, maintenance, and growth were from 2.0 -2.1 Mcal/kg, 2.2 to 2.3 Mcal/kg, 1.5 to 1.6 Mcal/kg, respectively. The feed milk value based on net energy for lactation ranged from 2.91 to 3.01 kg milk per kg DM.
Take home message: This study indicated that chickpea variety did not show a great impact on energy values, total digestible nutrients and feed milk value for dairy cows.

Effect of dairy cow personality traits on feeding and milking behaviour of cows milked in automated systems

A.J. Schwanke, J.E. Brasier, and T.J. DeVries
Department of Animal Biosciences, University of Guelph, tdevries@uoguelph.ca

Automated milking systems (AMS) allow dairy cows to be managed at a more individual level, through customized feed supplementation and milking permissions. However, differences in personality traits between cows can influence their feeding and milking behaviours. Three studies were conducted which aimed to investigate the relationship between cow personality traits and feeding and milking behaviors under: 1) different amounts of AMS concentrate (15 cows; 3.0 vs. 6.0 kg/d), 2) transitioning mid-lactation cows to an AMS with different AMS concentrate amounts (29 cows; 2.0 vs. 6.0 kg/d), and 3) transitioning fresh cows to an AMS (60 cows). Personality traits were assessed in each study through observation of behaviours in response to a novel environment, object, and human. In study 2 and 3, personality traits were consistent across the transition to an AMS. In study 1, more fearful cows were less likely to consume the maximum amount of AMS concentrate ($P<0.01$) and had greater daily variation in AMS concentrate delivery when allocated 6.0 kg/d ($P=0.05$). When transitioned to an AMS in mid-lactation in study 2, bolder cows who were provided more AMS concentrate were at lesser risk of problematic milkings ($P<0.01$) and had less daily variation in AMS concentrate delivery ($P=0.01$). Bolder cows who were provided more AMS concentrate were at lesser risk of sorting for long ($P<0.01$) feed particles, but at a greater risk of sorting for short ($P<0.01$) particles. More active cows who were provided with more AMS concentrate were at greater risk of problematic milkings during the first 3 days on the AMS ($P=0.05$). When transitioned to an AMS in the fresh period in study 3, more active cows had more voluntary AMS visits ($P=0.04$) and more successful milkings per day ($P=0.03$), while bolder multiparous cows produced more milk ($P<0.01$).
Take home message: The data from these studies indicate that dairy cow personality traits are consistent over several different management challenges, and influence feeding and milking behaviours, as well as performance when milked on an AMS.

Associations of herd-level housing and management practices during the dry period with early-lactation udder health in herds with automated milking systems

C.A. Wagemann-Fluxá, B.J. Van Soest, D.F. Kelton, and T.J. DeVries
University of Guelph tdevries@uoguelph.ca

The aim of this retrospective study was to identify herd-level housing and management practices during the dry period that are associated with udder health in early-lactation cows on automated milking system (AMS) farms. Data were collected from 166 commercial AMS farms (mean=116±111 milking cows) across Canada from 10/2018 – 09/2020. Producers were surveyed regarding housing and management practices. On each farm, we selected all cows (n=14,007) that had available DHI SCC information for their last milk test prior to dry-off (>250 DIM) and their first milk test after calving (5-45 DIM). Using SCC data, we calculated the somatic cell score (SCS) for the first milk test after calving (PostSCS) for each cow and the herd-average PostSCS (mean=2.43±0.60). Subclinical intramammary infection (IMI) was estimated using cow SCC data. Cows "not infected" (SCC<200,000 cells/mL) in their last test prior to dry-off but "infected" (SCC≥200,000 cells/mL) on their first test after calving, were categorized as cows with "new IMI". We then calculated the incidence risk of new IMI across the dry period for each herd (mean=16.5±9.3%). Higher herd-average PostSCS was associated with not using teat sealants at dry-off (P=0.01), not using blanket antibiotic dry cow therapy at dry-off (P<0.001), and not leaving cows in the same group during the entire dry period (P=0.01), and tended to be associated with not separating cows into a different pen as preparation for dry-off (P=0.06) and placing cows onto the AMS within the first day after calving (P=0.09). A lower incidence of new IMI was associated with housing dry cows in pack pens and stalls (P=0.02) as compared to only pack pens and with a higher herd-average 305-d milk yield (P=0.02), whereas a higher incidence of new IMI tended to be associated with not separating cows into a different pen as preparation for dry-off (P=0.08).
Take home message: Producers may be able to implement housing and management practices that improve udder health in early-lactation cows in AMS.

Bovine leukemia virus proviral load as a measure for selective removal of cattle for bovine leukosis control

Sulav Shrestha[1]*, Karin Orsel[1], Herman W. Barkema[1, 2], Guido van Marle[2], M. Faizal Abdul-Careem[1], Frank van der Meer[1]
[1]Faculty of Veterinary Medicine, [2]Cumming School of Medicine, University of Calgary, Calgary, AB, Canada. *sulav.shrestha1@ucalgary.ca

Bovine leukosis, which is caused by the bovine leukemia virus (BLV), is associated with low milk production, longevity, and immunity. However, controlling this disease is a challenge because of the high within-herd prevalence in Canadian dairy herds. Recent studies have indicated the role of BLV proviral load in BLV transmission and control, whereby removing high proviral load (HPL) animals helped in the reduction of BLV prevalence. The objective of this study was to assess the impact of selectively removing the HPL cows from the herd on the herd-level BLV prevalence. Also, the association of BLV proviral load on the milk production of cows was evaluated. Ten free-stall dairy herds across Alberta with an adult herd size ranging from 81 to 402 cows were enrolled in a three-year study. BLV status of each cow was annually assessed in milk or blood sample using an antibody detection ELISA and the proviral load with the BLV SS1 qPCR assay (CentralStar Cooperative Inc.). It was recommended to remove the HPL cows from the herd after each test. For the milk production association analysis, 305-day milk production records were obtained from Lactanet Canada to conduct a cross-sectional study. At the end of this study, the overall median herd-level BLV prevalence decreased from 29% in the first year to 23% in the third year. The results from the cross-sectional study demonstrated that HPL cows produce less milk than BLV-negative cows, however, this was not statistically significant. Our results indicate that information on BLV proviral load could be useful for BLV control and assessing the impact of BLV in the milk production of dairy cows.
Take home message: In situations of high within-herd prevalence, the removal of HPL animals could be a practical and economical strategy for BLV control.

Understanding the effects of different types of outdoor access on dairy cow health

A.M.C. Smid, B. Traub, and H.W. Barkema
Faculty of Veterinary Medicine, University of Calgary, Calgary, AB. Email: annemarieke.smid@ucalgary.ca

In 2021, <30% of Canadian dairy farms provide lactating cows outdoor access; <55% provide dry cows outdoor access. Given that Canadians view outdoor access as important for dairy cattle, it is crucial that the Canadian dairy industry effectively addresses this public concern, while fitting within the constraints of modern Canadian dairy farms. In a study to understand Western Canadian dairy farmers' perspectives on outdoor access for dairy cows, many farmer participants expressed concerns about the effects of outdoor access during the dry period on the incidence of transition diseases. Others had questions around the effects of outdoor access on mastitis incidence and hoof health. Indeed, research on transition diseases in dairy cattle have mainly focused on dairy cows kept indoors; research on transition diseases in dairy cows kept in outdoor systems is lacking. Therefore, we aim to understand the effects of different types of outdoor access (i.e., pasture and alternative outdoor areas) for lactating cows, dry cows, and pregnant heifers on the incidence of transition diseases and clinical mastitis, and hoof health. A total 35 herds with pasture access, 35 with alternative types of outdoor access and 35 without any form of outdoor access are recruited and followed for 1 year. Management of the participating farms is documented using surveys and by visual observations of the indoor and outdoor environments, before, during and after the outdoor seasons. All disease incidences are recorded by producers and their hoof trimmers; producers also collect a milk sample of each clinical mastitis case. By comparing health outcomes of farms with and without pasture or alternative types of outdoor access and within farms over time, we will investigate how various outdoor environments influence dairy cow health.
Take home messages: Better understanding the effects of different types of outdoor access on cow health will provide knowledge to help farmers make an informed decision around (implementing) outdoor access practices on their farm.

The impact of farm tours on public knowledge and perception of dairy farming

A.M.C. Smid[1], H.W. Barkema[1], B. Traub[1], and B.A. Ventura[2]
[1]Faculty of Veterinary Medicine, University of Calgary, Calgary, AB, Canada; [2]Department of Life Sciences, University of Lincoln, Lincoln, UK
annemarieke.smid@ucalgary.ca

Events such as 'Breakfast on the Dairy Farm' (BOTDF) are frequently used to educate the public about dairy farming, with the assumption that education will improve public perception of dairy farming. However, education does not necessarily lead to improved public perception, as people's views are shaped by factors beyond information. Therefore, we investigated the effects of different communication approaches (i.e., one-way education vs conversational style) by farmers on public knowledge and perception of dairy farming in Canada. Dairy farmers (n = 30) were trained to deliver one of the two conversation styles during farm tours at BOTDF events (n = 3) in Alberta. People attending the events were invited to take part in before- and after-tour surveys to assess a potential shift in peoples' knowledge and perception of dairy farming. A total 308 people filled out both surveys; 160 people also filled out a third survey 2 weeks after their tour. Overall, visitors' performance scores on a knowledge 'quiz' about dairy farming increased by 30% after the farm tour, regardless of communication approach. A total 41% of participants had become more positive in their perceptions toward dairy cow quality of life immediately after the tour, whereas 8% became more negative, with no differences between communication methods. However, when comparing peoples' perceptions after the farm tour with 2 weeks after the event, 27% had become more negative in their perceptions about dairy cow quality of life. The most frequent concerns focused on cow-calf separation and the lack of outdoor access.
Take home message: As public education does not necessarily lead to improved public perception of dairy farming it may be important for the dairy industry to create non-judgmental spaces for open dialogue to build better relationships between dairy farmers and the public. These conversations may help the dairy industry determine what factors are important for a socially sustainable dairy industry.

The effect of exogenous GnRH at the time of artificial insemination on luteinizing hormone in lactating Holstein cows

R.S. Conceicao[1], A. Bega[1], J.C.S. Marques[1], S. Moore[1], J. Denis-Robichaud[1], C. F. Baes[3], R.L.A. Cerri[1]
[1]University of British Columbia, Faculty of Land and Food Systems, Canada; [3]University of Guelph, Centre of Genetic Improvement of Livestock, Canada. E-mail: rckrebs@student.ubc.ca

This study aimed to evaluate the effect of gonadotropin releasing hormone (GnRH) at supposed time of AI on the profile of luteinizing hormone (LH) in spontaneous estrous from lactating Holstein cows. Lactating Holstein cows (n=42) were enrolled. Animals received a synchronization protocol and had their estrous cycle followed through plasma progesterone and ovarian ultrasonography until detection of the subsequent spontaneous estrous event. On the following estrus detected by an automated activity monitor, cows were randomly assigned into two experimental groups: GnRH (n=21), cows received an injection of 100 µg of GnRH (Fertiline, Vetoquinol), and Control (n=21), cows received an injection of 2 mL of saline solution at supposed time of AI (considered hour 0). Blood samples were collected prior to treatment and hourly for the following 6 hours to determine LH concentrations. A total of 42 animals were used in the analysis. Ovulation was observed in 40/42 of the cows following estrous event. The average LH before treatment was 2.0 ng/mL (0.11-7.58 ng/mL). The LH tended to decrease and was below 1 ng/mL 3-h post-treatment in most animals 28/42. Control cows had lower circulating LH 1-h post-treatment (Control=1.15±1.6; GnRH=3.16±2.36; P<0.001) compared to GnRH cows. LH concentration did not differ between groups 3-h post-treatment (P=0.55). There was no association between intensity of estrous expression and LH concentrations (P=0.52). In conclusion, this study demonstrated that intensity of estrous was not associated with LH levels in spontaneous estrous of lactating Holstein cows. The administration of GnRH at AI was shown to increase LH 1-h post-treatment. Cows presumably past their LH surge were lesser affected by GnRH, potentially because of a depletion in the LH reserve in the pituitary gland. Therefore, improvement in LH promoted by GnRH at the time of artificial insemination could elicit benefits on dairy cow's fertility. Future research is needed to elucidate the role of GnRH during AI on spontaneous estrous of lactating Holstein cows.
Take home message: Administration of GnRH at the time of artificial insemination potentially increases circulating LH which could lead to benefits in fertility of lactating Holstein cows.

Do transition milk and colostrum feedings provide benefits to dairy calves' gastrointestinal tract after transportation?

M.Tortadès,[1] S. Martí,[1] M. Devant[1] and M. Terré[1]
[1]Department of Ruminant Production, IRTA, 08140 Caldes de Montbui, Spain. Email:marina.tortades@irta.cat

Bovine colostrum (**BC**) and Transition milk (**TM**) are rich in nutrients and bioactive molecules, which may help calves to recover digestive tract functionality from stressful periods such as marketing and transport. The objective of our study was to evaluate the digestive tract recovery of feeding either BC, TM, or milk replacer (MR) transportation. In this conference, we will assess our objective through fecal biomarkers of immune response and microbiota. The transportation was simulated by restrictive feeding 2L of an oral rehydration solution twice daily for 3 d and 19 h of fasting to 35 male calves (22 ± 4.8 days old) and then randomly assigned the calves to one of 5 treatments (n=7; d 1 of study): feeding either pooled BC during four (**C4**) or ten (**C10**) days, pooled TM during four (**TM4**) or ten (**TM10**) days, or MR for ten days (**CTRL**) at the rate of 720 g/d DM content in a total volume of 3L. After, all calves were fed the same feeding program, decreasing MR gradually from 3L twice daily to 2L once daily at 12.5% DM until weaning (d 42 of study). Concentrate feed, water, and straw were offered *ad libitum*. Feed, MR, and straw intake were recorded daily, and body weight on d -3, 1, 2, 5 and 11, and weekly afterwards. Volatile fatty acids, IgA and microbiota (Firmicutes to Bacteroidetes ratio and *Faecalis prausnitzii*) were analyzed in feces from samples obtained on d 5 and 11 before the morning feeding. Calf performance, intake, and microbiota quantification were similar among treatments throughout the study. Fecal IgA concentrations were greater ($P < 0.05$) in C10 than in CTRL, TM4, and TM10 calves, and in C4 and TM10 than in CTRL animals. Fecal propionate proportion was less abundant in C10 calves than in CTRL, TM4 and TM10 ones, while butyrate was greater in C4 and C10 calves than in TM4 and CTRL ones.
Take home message: TM and BC provide gut immune protection and BC may promote butyrate-producing bacteria in calves after transportation.

Effects of weaning strategies on health, hematology, and productivity in Holstein dairy calves

A. Wolfe[1,2], P. Rezamand[1], B. C. Agustinho[1], D. E. Konetchy[1], A. H. Laarman[2]
University of Idaho[1], University of Alberta[2,] arwolfe@ualberta.ca

Weaning strategies in dairy calves vary considerably, though the impact on animal health is unclear. This study examined the effects of calf weaning age (6 vs. 8 wk) and pace (abrupt vs. gradual) on health parameters in dairy calves. Holstein calves (n = 72), blocked by sex and birth weight, were randomly assigned to one of four treatments (n = 18 per): Early-Abrupt (EA), Early-Gradual (EG), Late-Abrupt (LA), and Late-Gradual (LG). Milk replacer (24% CP, 17% fat; up to 1200 g/d) was fed twice daily; water, calf starter (18% CP), and chopped alfalfa hay were fed ad libitum Body weight, health measures, blood hematology, and fecal scores were obtained prior to, and after weaning. Calves were orally bolused with a rumen pH logger for the last three days of the weaning transition and rumen pH was measured continuously. Calves also had fresh blood analyzed using an HM5 hematology unit during weaning to determine immune function. Age at weaning increased respiration, while gradual weaning groups had lower respiration rate. Heartrate was lower in gradual than in abrupt groups. Fecal score tended to increase in late-weaned groups and gradually-weaned groups. No difference was detected in body core temperature by age or pace. During the weaning transition, average daily gain was lower in LA than EA (0.62 vs. 0.11 Kg/d) and gradually-weaned groups had increased ADG (0.65 kg/d). Change in grain intake, but not forage intake, was greater in gradually-weaned groups. Mean rumen pH tended to increase from EG to LG (7.65 vs. 8.84) and from LA to LG (7.89 vs. 8.84). Overall, calf health is affected by both age and pace of weaning, though the health parameters impacted by age and pace differ.
Take home message: From the above data we determined that weaning at 8 weeks improved health of young calves. We also saw that gradual weaning demonstrated benefits to the rumen environment in the form of grain intake and rumen pH. Combining age and pace demonstrated that gradual weaning at an earlier age increases average daily gains and provides more consistent intakes.

Within-herd transmission of *Mycoplasma bovis* infection in 20 Dutch dairy herds

Biesheuvel MM, Faculty of Veterinary Medicine, University of Calgary, CA
Marit.biesheuvel@ucalgary.ca

Even though *Mycoplasma bovis* is an emerging disease in Western Canada, causing recent outbreaks on dairy farms across Alberta, understanding outbreak dynamics remain limited and inconclusive. Detailed, quantified information about how and at what rate *M. bovis* spreads on-farm between age groups is lacking, whilst being critical for outbreak control. We, therefore, aimed to estimate the within-herd transmission of *M. bovis* and the most likely transmission pathways between calves, youngstock and cows using an age-stratified SIR model on 3 individual test results and identify potential risk factors explaining transmission patterns using a Fisher's exact test. A cohort of the 3 cattle age groups on 20 Dutch dairy farms with a clinical outbreak of *M. bovis* in adult cows was sampled 5 times during a 12-week period. Transmission from cows was associated with median reproduction ratios of 28 (95%CI: 4 – 55), 27 (95%CI: 4 – 30) and 30 (95%CI: 3 – 46) secondarily infected cows, youngstock, and calves per herd. Transmission from youngstock with 7 (95%CI: 2 – 46), 3 (95%CI: 0 – 74) and 2 (95%CI: 0 – 60) secondarily infected youngstock, calves and cows per herd, whereas transmission from calves with 8 (95%CI: 2 – 39), 6 (95%CI: 2 – 15) and 9 (95%CI: 0 – 46) secondarily infected calves, youngstock and cows per herd. Mean duration of the outbreaks ranged from 5.3 to 55 weeks across the 20 herds. Most important pathways were transmission from cows to youngstock, calves and cows, but also pathways from calves to calves and youngstock, and youngstock to youngstock (>50% of the farms) occurred frequently. Risk factors could be related to internal biosecurity (number of people involved in caretaking), external biosecurity (contractors, external employees) or indirect transmission routes (number of feed and water stations).
Take home message: This study demonstrates that *M. bovis* can spread incredibly fast, with most transmission originating from cows to cows, youngstock and calves. However, transmission to and amongst calves and youngstock should not be ignored, given their relevance in many on-farm outbreaks.

Effect of selective clinical mastitis treatments on cure, somatic cell count, recurrence and culling: Systematic review and meta-analysis

Ellen de Jong
Faculty of Veterinary Medicine, University of Calgary, Calgary, AB. ellen.dejong1@ucalgary.ca

Objectives. Clinical mastitis (CM) treatments greatly contribute to antimicrobial use on dairy farms. Selective treatment of CM can reduce antimicrobial use, as only CM cases identified as Gram-positive benefit of antimicrobial treatment. Impacts of selective CM treatment on udder health and culling are not fully understood. Methods. A systematic search identified 12 studies that compared selective versus blanket CM treatment protocols. Reported outcomes were synthesized with random-effects models and presented as risk ratios (RR) or mean differences (MD) with their 95% confidence intervals (CI). Results. A selective treatment protocol of CM was not inferior to a blanket treatment protocol for bacteriological cure (RR 1.09; 95% CI: 0.87 – 1.36). Cases in the selective treatment group experienced a higher clinical cure within 14 d (RR 0.75; 95% CI: 0.58 – 0.97) and 0.4 d longer till clinical cure (95% CI: 0.19 – 0.69), but these results were confounded by co-administration of NSAIDs in this group compared with no use of NSAIDs in the blanket treatment group. Furthermore, there was no difference between selective and blanket treated CM cases for: proportion that developed another intramammary infection within 21 d (RR 0.96; 95% CI: 0.81 – 1.14), proportion with high somatic cell count after 21 d (RR 1.00, 95% CI: 0.94 – 1.06), average somatic cell score (MD 0.04; 95% CI: -0.10 – 0.11), average milk yield (MD 0.34, 95% CI: -0.67 – 1.35), recurrence (RR 0.91; 95% CI: 0.73 – 1.13) and culling (RR 0.87; 95% CI: 0.70 – 1.08). However, for these parameters non-inferiority margins could not be determined. Conclusions. When comparing cows treated with a selective to a blanket CM treatment protocol, no differences were identified in bacteriological cure, clinical cure, intramammary infection risk, milk yield, somatic cell count, recurrence, and culling.
Take home message: Available data support that a selective CM treatment protocol can be adopted without negative udder health consequences.

Postpartum health is associated with detection of estrus by activity monitors in dairy cows

T.C. Bruinjé,[1] E.I. Morrison,[1] E.S. Ribeiro,[2] D. Renaud,[1] R. Couto Serrenho,[1] S.J. LeBlanc,[1]
[1]Population Medicine, University of Guelph; [2]Animal Biosciences, University of Guelph. E-mail: tbruinje@uoguelph.ca

Over 80% of Canadian dairies use some estrus detection in reproductive management. Being able to identify cows more or less likely to be detected in estrus based on their health status would optimize reproductive management and performance. Our objective was to investigate associations of postpartum health with detection of estrus by activity monitors. In Holstein cows (n = 1,210) from 2 commercial herds in Ontario, serum concentrations of total Ca, haptoglobin, and NEFA were measured at 2 and 6 (±1) DIM, and blood BHB and metritis (with Metricheck) were assessed at 4, 8, 11, and 15 (±1) DIM. Purulent vaginal discharge (PVD) and endometritis (based on endometrial cytology sampled by cytobrush) were examined at week 5. Body condition score (BCS) and lameness were assessed throughout the study, and additional disease data obtained from farm records. Serum progesterone was measured biweekly from week 3 to 9. First AI was primarily based on estrus detection by activity monitors (Afimilk or SCR Engineers Ltd.) without synchronization between 50 and 75 DIM. Continuous variables were categorized with ROC analysis associated with estrus detection, and data analyzed using multivariable mixed logistic regression models. Estrus detection occurred in 71% of cows. Compared to cows without each of these risk factors, estrus detection was less likely in cows with retained placenta (61 vs. 73%), haptoglobin ≥ 0.47 g/L at 6 DIM (69 vs. 75%), BHB ≥ 0.7 m*M* in 2 or more samples (69 vs. 79%), PVD (66 vs. 73%), endometritis (≥ 2% polymorphonuclear cells; 67 vs. 76%), ≥ 0.5-point BCS loss by week 9 (67 vs. 80%), or in cows anovular by 49 DIM (61 vs. 74%).
Take home message: Based on postpartum health variables, farmers could identify cows that are more or less likely to be detected in estrus, allowing selective use of synchronization and optimized performance using activity monitors as a primary tool for reproductive management.

Effect of transition diet starch content, parity, and milking number on total sialic acids in the protein and carbohydrate fractions of colostrum and transition milk of Holstein dairy cattle

A.J. Fischer-Tlustos[1], J. Haisan[2], W. Shi[2], K. Narayana[3], C. Tomiyama[3], S. Bakker[3], J.P. Cant[1], M. Oba[2], W.F. Zandberg[3], and M.A. Steele[1]
[1]Department of Animal Biosciences, University of Guelph, Guelph, ON, Canada N1G 2W1; [2]Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB, Canada T6G 2P5; [3]Department of Biology, University of British Columbia, Kelowna, BC, Canada V1V 1V7. Corresponding author: masteele@uoguelph.ca

Colostrum and milk sialic acids (SA) are beneficial compounds that can promote immunity and gut development in neonates; yet strategies to maximize the amount of SA produced by the dam are unknown. To determine how close-up diet starch content affects colostrum SA levels and how both close-up and fresh diet starch content affects the SA profile of transition milk (TM; milkings (M) 2-6), multiparous (MP; n = 51) and primiparous (PP; n = 36) Holstein cows were assigned to a close-up diet containing moderate (CON; 14.0% starch, %DM) or high (HI; 26.1% starch, %DM) starch from 28 d prior to expected calving date, and to a high fibre (HF; 33.8% NDF, 25.1% starch, %DM) or high starch (HS; 27.2% NDF, 32.8% starch, %DM) diet after calving. In the carbohydrate and protein fraction of colostrum, total SA yields were 25.4 ± 1.90 and 2.2 ± 0.22 g, respectively, and protein total SA yield was positively correlated with IgG yield (r = 0.76; $P < 0.0001$). Carbohydrate and protein total SA concentrations decreased ($P < 0.0001$) by 34 and 90%, respectively, from colostrum to M6. MP cows produced 1.6 and 2.5x greater ($P < 0.0003$) SA yield in the carbohydrate and protein fraction, respectively, from M1-6 compared to PP cows. Transition diet had no effect ($P = 0.98$) on carbohydrate SA; however, feeding CON tended ($P = 0.06$) to increase protein total SA concentration from M1-6 by 25% compared to feeding HI.
Take Home Message: Moderate starch inclusion during close-up can improve concentrations of protein SA in colostrum and TM and may be a feasible strategy to increase the amount of SA consumed by the calf to promote optimal development in early life.

Assessment of hindgut microbial functional shift related to nutritional diarrhea in postpartum dairy cows

Yangyi Hao[1,2] Le Luo Guan[*, 1] and Shengli Li[†2]
[1]University of Alberta, Canada Email: *lguan@ualberta.ca, [2]China Agricultural University, China Email: †lisheng0677@163.com

Nutritional diarrhea is an easily neglected health issue in postpartum dairy cows (PDC) and as a result, some cows can develop enteritis. Our study aimed to identify the physiological and metabolic changes when PDC developed nutritional diarrhea and to assess whether it affects their milking production performance. Twenty-four cows were selected from 200 PDC and separated into two groups based on the difference in their fecal scores: low fecal score (LFS) group (1.33 ± 0.42, mean ± SD, n = 12) and high fecal score (HFS) group (3.00 ± 0.29, n = 12), and ruled out of the bovine viral diarrhea and paratuberculosis. All these cows had similar body weights, parity, and days in milk. The fecal dry matter content in LFS (9.32 % ± 1.22) was lower ($P < 0.01$) than that in HFS group (13.55 % ± 0.70). Milk yield during the postpartum period was significantly higher ($P < 0.05$) in LFS than that in HFS cows, which was affected by the interaction between cow's diarrhea and days in milk. Milk β-hydroxybutyric acid (BHBA) and acetone concentrations as well as ruminal propionate concentration were higher ($P < 0.05$) in LFS cows than those in HFS. The apparent digestibility of crude protein in LFS cows trended to be lower ($P < 0.10$) than that in HFS cows. In addition, LFS cows had higher ($P < 0.05$) fecal ammonia nitrate concentration, isobutyrate, and isovalerate molar proportions and lower ($P < 0.05$) acetate and total volatile fatty acid concentrations than HFS cows.
Take home message: Our results suggest that the dysbiosis in hindgut microbiota may contribute to diarrhea in PDC, resulting in altered protein digestibility and milk BHBA and acetone concentrations, which warrant future research. Take home message: Although the cow's performance may not be affected by nutritional diarrhea, the observed altered microbial fermentation parameters suggest the changes in the gut microbiota, which may have long-term consequences for the cow's performance and health.

Effect of iodine source on dairy cow colostrum production and growth and health of their calves

K.R. Johnston[a,b], D.C. Reyes[a], K.N. Klobucher[a], T.C. Stahl[a], P.S. Erickson[a], and A.F. Brito[a]
[a]University of New Hampshire, Durham, New Hampshire, United States; Email: krjohns2@ualberta.ca

There is limited research on how high iodine (**I**) concentrations in seaweed meal affects prepartum cow colostrum production and development of their calves. The objectives of this study were: (1) evaluate the effects of incremental amounts of *Ascophyllum nodosum* (**ASCO**) meal supplementation to prepartum cows on colostrum production and the growth and blood metabolites of their calves, and (2) compare ASCO meal versus an inorganic I source (ethylenediamine dihydroiodide) on the same variables under objective 1. Forty Holstein cows were blocked by lactation number and calving date and assigned to 1 of 4 treatments 28 d prior to parturition: 0 g/d ASCO meal (**CON**), 57 g/d of ASCO meal (**LO**), 113 g/d ASCO meal (**HI**), and EDDI (124.8 mg/d) matching the amount of I in HI (**EDDI**). Colostrum was harvested within 1 h of calving. Forty-one calves were blocked based on their dams' treatments. Calves were fed 300 g IgG via colostrum replacer. At 24 h, calves were offered 676 g/d dry matter of milk replacer (**MR**) until 49 d, where they were offered 338 g of MR. Free choice textured starter and water were offered ad libitum starting from 24 h of age. Colostral fat concentration was greater in HI than EDDI cows, and there was a tendency for fat concentration to decrease linearly with ASCO meal supplementation. Colostral I was unaffected by treatment. Calves born to HI dams had larger birth weights than EDDI calves and calf body weight gain over 8 wks tended to decrease linearly with ASCO meal. Plasma concentration of total T_4, and beta-hydroxybutyrate responded quadratically to ASCO meal supplementation. There was a tendency for IgG apparent efficiency of absorption to be lower in EDDI versus HI calves.
Take home message: addition of ASCO meal to the dams' diet did not negatively impact calf growth and metabolism or colostrum production. Additionally, ASCO may benefit colostrum composition and calf passive transfer when used as an I source compared to EDDI.

The use of an optimized protocol to isolate eight novel bacteriophages with the ability to lyse MAP

Victoria Harman-Mckenna and Jeroen De Buck
Faculty of Veterinary Medicine, University of Calgary, Victoria.harmanmcken@ucalgary.ca, jdebuck@ucalgary.ca

Johne's disease (JD) is a chronic infectious enteritis of ruminants and causes losses of $90 million CAD to the Canadian dairy industry annually. This enteritis is caused by *Mycobacterium avium* subsp. *paratuberculosis* (MAP). JD spreads among youngstock through the ingestion of feed and water contaminated with infectious faeces. Currently there is no cure for JD and due to the long incubation time of the disease, test-based culling has proved ineffective at preventing the spread of JD. Mycobacteriophages, viruses with the capacity to kill mycobacteria, have potential as anti-mycobacterial agents. They have been used successfully to control mycobacterial infections such as those caused by *M. avium*. Isolation of new MAP lysing bacteriophages is an important step to using phages to control JD infection. We optimised an isolation protocol by faecal spiking and the testing of different isolation solution compositions. We screened 475 environmental samples for the presence of mycobacteriophages through phage enrichment with both MAP and the fast-growing *M. smegmatis*. These samples were taken from farms with a known JD presence. Samples included soil, manure pits, lactation barn, faeces straight from the cows, milk and drain water. We isolated 14 phages. After fingerprinting these phages by restriction enzyme profiling, we concluded that 11 of those phages isolated were distinct and novel. Further characterisation of their host range shows that 8 are capable of lysing genetically different MAP strains. We have further characterised the cross resistance, lysogeny and effect of pH on these novel phages. Eight novel mycobacteriophages, with a variable capacity to lyse distinct MAP strains, were discovered and characterized.
Take home message: Newly isolated mycobacteriophages have the potential to be used in strategies to prevent the spread of JD on diary farms. We recommend the use of a cocktail of different phages in the preventative strategies given their variable host range.

Assessing herd-level Johne's disease prevalence based on environmental samples

Larissa Martins[1,2], Karin Orsel[1], Jeroen De Buck[1], Herman W. Barkema[1]
[1]Department of Production Animal Health, Faculty of Veterinary Medicine, University of Calgary: larissa.martins@ucalgary.ca

Detecting Mycobacterium avium subsp. paratuberculosis (MAP) in environmental samples by culturing methods followed by qPCR has adequate sensitivity (Se) and specificity (Sp). Although the Se of the method is acceptable, the culturing protocol is expensive due to specific materials required to stimulate MAP growth and the protocol takes up to 50 days to be completed. Direct MAP detection relying on efficient DNA extraction methods followed by qPCR is an alternative due to its efficiency. Improvements of the Se and Sp of this method might come from changing the MAP target gene, as most single-copy MAP-specific genes are less sensitive. The aim of the study was to evaluate the accuracy of different MAP-specific target genes to detect MAP-positive environmental samples. Environmental samples were collected on 24 Alberta dairy farms. At each farm, 3 sets of samples were collected from the lactating cow barn and manure storage areas. DNA was extracted followed by qPCR targeting the following genes IS900, F57, ISMAP02, hspX, mbtA-MAP217, MAP0865 and 251. Of the 24 farms, 42% of farms were positive by IS900, while 25% were positive by ISMAP02. Additionally, 8% of the farms were identified as MAP positive by the single copy genes F57, mbtA-MAP217, MAP0865, 251, while 4% of farms were identified as positive by hspX. IS900 and ISMAP02 detected a higher percentage of MAP positive farms compared to the other target genes, but a higher sample size is still required to determine which MAP target gene will be the best one to be included into the detection of the herd-level MAP prevalence based on environmental samples and perhaps the development of a multiplex qPCR will improve the Se and Sp of the test.
Take home message: The research will provide a less expensive and more accurate diagnostic test to detect MAP-positive farms based on environmental samples. The IS900 and ISMAP02 target-genes are more sensitive to detect MAP on environmental samples compared to F57, mbtA-MAP217, MAP0865, 251 and hspX.

The impact of progesterone concentrations during superovulation of Holstein heifers in a randomized trial

J.C.S. Marques,[1*] J.P.O Maciel,[2] J. Denis-Robichaud,[1] R.S. Conceicao,[1] A.M. Bega[3], S. Moore,[1] R.L.A. Cerri[1]
[1]Faculty of Land and Food Systems, University of British Columbia, Canada; [2]Faculty of Veterinary Medicine, Rural Federal University of Pernambuco, Brazil; [3]Faculty of Veterinary Medicine, São Paulo State University, Brazil.
*jessica.dossantosmarques@ubc.ca

The aim of this study was to evaluate the effect of different progesterone (P4) concentrations during the follicular growth on the intensity of estrous expression, and embryo production and quality in superovulated heifers. A total of 63 Holstein heifers were randomly assigned into two experimental groups: Low P4 (n = 31) and High P4 (n = 32). Animals received a pre-synchronization protocol followed by a protocol of superovulation that included the allocated P4 treatment. Activity was monitored continuously by an automated activity monitor, and estrus characteristics (maximum intensity and duration) were recorded. Embryo collection was performed 7d post artificial insemination (AI). Embryos were counted and graded from good/excellent (1) to degenerated (4). A total of 105 embryos (High P4 =42; Low P4=63) were graded for quality. Different P4 levels did not affect the maximum intensity (High P4=497.8 ± 23.9; Low P4=542.2 ± 23.5%; P = 0.19) or the duration (High P4=13.5 ± 1.5; Low P4=14.3 ± 1.4 h; P = 0.70) of estrus. High P4 heifers tended to have better embryo quality when compared to Low P4 (OR=1.98; P = 0.08). However, Low P4 heifers had 2.48 times greater number of embryos when compared to High P4 (P = 0.03). Although estrous expression was not associated to embryo quality, the number of embryos recovered 7d post-AI was shown to be 1.04 and 1.5 times higher as the duration and the intensity of estrous expression increased, respectively (P > 0.01).
Take home message: supplementation with P4 prior to estrus might have the potential to increase the probability of pregnancy in embryo transfer programs by increasing the quality of transferable embryos. In addition, expression of estrus of greater intensity and duration may be an important marker of improved embryo production in superovulated heifers.

Effects of raw and steam pressure toasted faba bean seeds in diets of high producing dairy cows

María E. Rodríguez Espinosa, David Christensen, Rex W. Newkirk, Yongfeng Ai, Victor H. Guevara Oquendo[a], and Peiqiang Yu*
Department of Animal and Poultry Science, College of Agriculture and Bioresources, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5A8, Canada. *Corresponding author: peiqiang.yu@usask.ca

The existence of alternative feed ingredients of good nutritional value is important for the livestock industry. Introducing new feeding options requires reliable information to prove beneficial or detrimental impacts on animal productivity. This study aimed to evaluate the use of raw or steam pressure toasted Faba bean seeds (FBS) as an alternative for traditional feeding ingredients such as soybean and barley grain. Snowbird FBS were processed by steam pressure toasting (SPT) at 121°C for 0, 7.5, 15, and 30 min using a thermal hydrolysis batch reactor (Saskatoon Boiler Mfg.). Rolled FBS (10% inclusion in total mixed rations, TMR) were fed to lactating Holstein cows (2nd and 3rd lactation, 69 ± 15 days in milk, and 720 kg mean body weight) for 120 days. Data were analyzed with the MIXED procedure of SAS 9.4, using a double Latin Square (4x4) design model with treatment as the fixed effect and cow as the random effects. Polynomial contrasts were used to evaluate the effects of SPT duration and significance was declared at P<0.05. The average milk yield and fat content for all the diets were 39.4 kg/cow/day and 3.86%, respectively (P>0.10). Milk urea nitrogen (MUN) decreased from 12.18 with TMR_0 to 11.10 mg/dl with TMR_30 (linear P<0.01). Based on the current findings, a potential use for FBS in ruminant diets is presumed, as no negative effects were observed on the production performance of high producing dairy cows.
Take home message: FBS could be a promising feed alternative for the dairy industry as partial replacement for soybean meal and barley grain. Optimal processing method, processing time, and level of inclusion of FBS remain broad fields of research in ruminant systems to find the best revenue and profits for the dairy industry.

Herd-level prevalence of bovine leukosis and neosporosis in Alberta dairy herds using bulk tank milk samples

Waseem Shaukat[1*], Ellen de Jong[1], Kayley D. McCubbin[1], Marit Biesheuvel[1], Karin Orsel[1,2], Herman W. Barkema[1,2,3]
[1] Faculty of Veterinary Medicine, University of Calgary, Calgary, Alberta, Canada; [2] Department of Community Health Sciences, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada; [3] One Health at UCalgary, University of Calgary, Calgary, Alberta, Canada.
* waseem.shaukat@ucalgary.ca

Endemic infectious diseases remain a major challenge for Canadian dairy farms. The Cattle Health Surveillance System (CHeSS) project offers a more comprehensive approach for the surveillance and control of multiple endemic infectious diseases of importance in Western Canada. For effective disease control programs, up-to-date estimates of the disease occurrence are of utmost importance. The objective of this study was to estimate the herd-level prevalence of bovine leukosis and neosporosis in Alberta, Canada, dairy farms. Bulk tank milk samples from all Alberta dairy farms (n = 489) were collected in December 2021, April 2022, July 2022, and October 2022, and tested for antibodies against bovine leukemia virus (BLV) and *Neospora caninum* using indirect ELISAs with Bovicheck BLV and IDEXX Neospora X2, respectively. ELISA results were dichotomized (positive and negative) based on the cut-off values as per manufacturers' recommendation. Herd-level prevalence was calculated as proportion of positive samples of total tested samples. Herd-level prevalence of BLV was estimated at 89.4% (95% CI = 86.3 – 91.9%), 88.7% (95% CI = 85.6 – 91.2%), 87.1% (95% CI = 83.8 – 89.8%), and 86.9% (95% CI = 83.5 – 89.6%) in December, April, July and October, respectively, while herd-level prevalence of *Neospora caninum* was estimated at 18.2% (95% CI = 15.0 – 21.9%), 7.2% (95% CI = 5.2 – 9.9%), 7.6% (95% CI = 5.5 – 10.3%), and 15.0% (95% CI = 12.1 – 18.5%), in December, April, July and October, respectively.
Take home message: These results provide up to date information of the disease frequency that will set the basis for further investigation of within-herd prevalence of these diseases and help in devising appropriate disease control strategies in Alberta.

The effect of high and low progesterone exposure treatments in a crossover trial on estrous expression and ovulation timing in Holstein heifers

A. L. Boyle,[*1] J. C. S. Marques,[1] S. M. Moore, [1] A. Bega,[1] J. Denis-Robichaud,[1] A. M. L. Madureira,[2] T.A. Burnett,[2] C. F. Baes,[3] R. L.A. Cerri[1]
[1]Applied Animal Biology, Faculty of Land and Food Systems, University of British Columbia, Vancouver, BC, Canada V6T 1Z4, [2]University of Guelph, Ridgetown Campus, Ridgetown, ON, N0P 2C0 Canada, [3]Centre for Genetic Improvement of Livestock, University of Guelph, Guelph, ON, Canada, N1G 2W1. *ainsley.moore@ubc.ca

The aim of this study was to evaluate the associations between progesterone (P4) concentrations during diestrus with intensity of estrous expression and time from estrus to ovulation in nulliparous Holstein cows. In a randomized cross-over design experiment, post-pubertal heifers (n=31) were pre-synchronized and fitted with a leg-mounted automated activity monitor (AAM). On d-17 relative to estrus, the animals received GnRH, P4 implant for 7 d and GnRH again on d-8. From d-7 to -1, heifers in the high P4 group (HP4) received a new CIDR while the heifers in the low P4 group (LP4) received a second use CIDR. Additionally, heifers in LP4 received multiple PGF2α injection during the diestrus. Heifers in both treatment groups received PGF2α on d-1, and estradiol cypionate on d0. Upon estrus activity alert, and every 4 h after until ovulation, the ovaries of the heifers were scanned by ultrasonography for the occurrence of ovulation. Blood samples were taken at estrus and 7 d later for P4 analysis. The HP4 treatment had significantly lower P4 concentrations on d0 than the LP4 treatment (P=0.001) and a tendency for higher P4 on d7 after the HP4 treatment (P=0.07). There was no effect of treatment on ovulation timing (HR=1.17, 95% CI=0.69–1.98, P=0.56). Estrous expression was not affected by treatment when measured by Duration (HP4: 17.7±0.8 vs LP4: 17.4±0.8; P=0.72) or Relative Increase of activity (HP4: 364.4±24.6 vs LP4: 344.6±24.6; P=0.55).
Take home message: Heifers with low P4 during diestrus had higher P4 on the day of estrus and a tendency for lower P4 7 d after than heifers with high P4 during the diestrus, but no associations were found for OT or estrous expression.

Managing and Sustaining Genetic Diversity in Dairy Systems

C. Baes[1,2], A. Fleming[3], B. Makanjuola[1], C. Obari[1], P. Sullivan[3], F.S. Schenkel[1], F. Miglior[1,3]

[1]Centre for Genetic Improvement of Livestock, Department of Animal Biosciences, University of Guelph, Ontario; [2] Vetsuisse Faculty, Institute of Genetics, University of Bern, Switzerland; [3]Lactanet Canada, Guelph, Ontario.
Contact: cbaes@uoguelph.ca

Take Home Messages

- Inbreeding levels are increasing and this increase is unavoidable.
- The precision of inbreeding values depends on the depth and completeness of the available pedigree, and the inclusion or not of genomic information.
- Many consequences of inbreeding are still unknown.
- Mating decisions can be used to balance genetic gain with increases in inbreeding levels. In some cases, a sacrifice in genetic gain is required to conserve genetic diversity.
- Genetic diversity, economics, and societal acceptance will play an increasing role in how selection programs evolve.

Introduction

Inbreeding occurs when related animals are mated, indicating that the two animals share a common ancestor in their pedigrees. The degree of inbreeding indicates how closely these relatives are related across the sire and dam lines. Mating two closely related animals results in a higher inbreeding coefficient than mating two distantly related animals. The traditional method of measuring inbreeding uses pedigree data that traces the pedigree back through multiple generations to identify common ancestors between the sire and dam. The precision of inbreeding values is thus highly dependent on the depth and completeness of the pedigree. A low inbreeding value may just be the result of a shallow or incomplete pedigree that excludes any shared ancestors. If the pedigree is traced further back, for example, three or four generations, there is a higher probability of finding a common ancestor that would contribute to a higher inbreeding coefficient.

The Impact of Genomics on Diversity

The earliest data for comparing and selecting dairy cattle came from pedigree, dairy production recording programs, and a ‘good eye.’ With the passage of time, a greater knowledge of heredity in dairy cows evolved into breeding science. Major advances, such as the invention of selection index theory and best linear unbiased prediction, as well as the introduction of artificial insemination and other reproductive technologies, aided in the acceleration of genetic progress. Recently, genomic selection has transformed the way we breed cattle.

The development of genomic technologies has accelerated in the last decade. In contrast to genetics, which is the study of heredity using traditional, theoretical ideas and models, genomics gets closer to the function and structure of complete genomes using molecular information from an animal’s DNA. Initially, different types of genetic markers were used for parentage verification and genetic defect testing. Nowadays, single nucleotide polymorphisms (SNP) are the markers of choice, because there are a lot of them in the DNA and they are relatively cost-effective to identify. SNP markers are now used to provide the information needed for genomic selection because they are inexpensive, abundant in the bovine genome, stably inherited, and suited for rapid analysis. Additionally, they are often inherited together with genes controlling traits of economic importance, such as milk production, growth rate, and height. These markers can also be used to more accurately estimate the relationships that exist among animals.

The Illumina Bovine SNP50 chip, released in 2008, enabled genotyping of over 50,000 SNP at the same time, which changed the way we breed dairy cattle and now also many other livestock species. While these SNP account for only a small percentage of the overall genomic diversity in the genome, they provide important information for improving the accuracy of genetic evaluation models. The use of genomic selection in dairy breeding has increased genetic gain for many traits and has changed how we select the next generation of animals. The ability to correctly choose the best animals has improved greatly through the use of genomic information, but it will further improve as additional genomic technologies mature. There is still a long way to go before all of the information in the genome (about 3 billion base pairs per animal) can be understood and used in selection systems, but we're off to a great start. The information found in the DNA can be used to follow which alleles of the genes, i.e., alternate forms of the genes, have been passed on from sire and dam to offspring.

Although genomic information has altered how candidates are chosen and the rate at which genetic progress is made, Howard et al. (2017) argued that a similar degree of change has yet to be seen in the use of genomic information to manage genetic diversity and unfavourable inbreeding effects in dairy populations (Baes et al., 2019).

▪ Inbreeding Levels Are on the Rise

With all the benefits of genomic information, there are also some challenges. Genomic selection has resulted in higher rates of genetic gain, but it has also sped up the yearly increase of inbreeding (Figure 1).

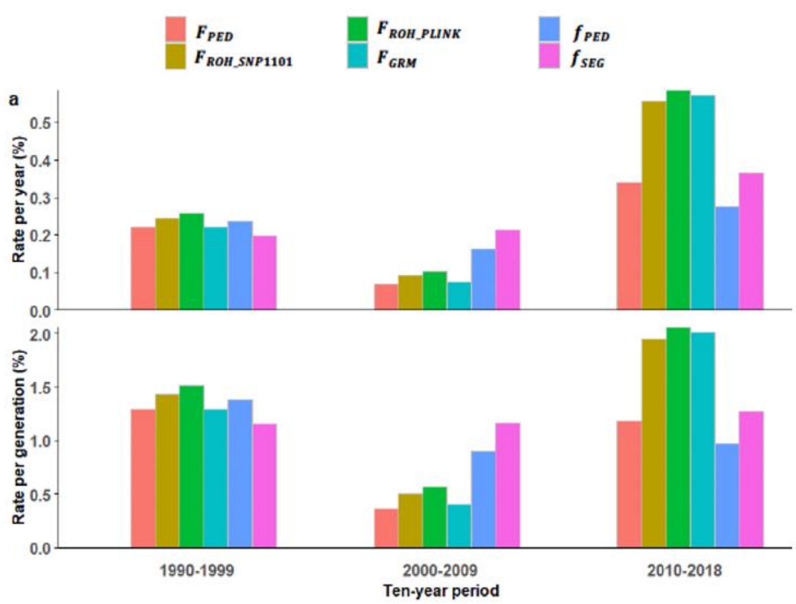

Figure 1: Rate of inbreeding and co-ancestry in North American Holsteins based on pedigree and genomic measures within ten-year periods from 1990 to 2018. F_{PED} = pedigree-based inbreeding; $F_{ROH\_SNP1101}$ = Genomic inbreeding based on Runs of Homozygosity) estimated using the software SNP1101; F_{ROH_PLINK} = Genomic inbreeding based on Runs of Homozygosity estimated using the software PLINK; F_{GRM} = Genomic inbreeding estimated using a marker-by-marker approach by subtracting one from elements of the genomic relationship matrix (fixed allele frequency of 0.5); f_{PED} = coefficient of co-ancestry using pedigree information; f_{SEG} = coefficient of co-ancestry using genomic information; adapted from Makanjuola et al., 2020.

This increasing rate of yearly inbreeding is mostly due to shorter generation intervals, which is an important consequence of the increased usage of genomically tested young sires (and younger animals in general), after 2009 (Figure 2). The decrease in generation interval is seen particularly in the male paths of selection (the age of sires of bulls and sires of cows decreased rapidly after 2009).

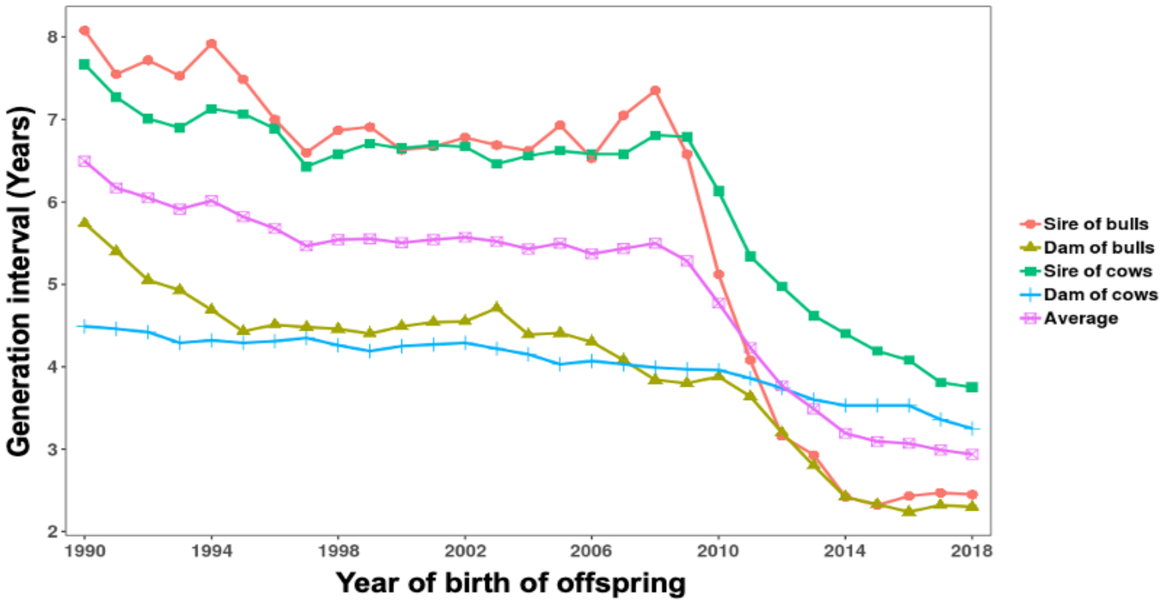

Figure 2: Length of generation interval (years) in North American Holsteins adapted from Makanjuola et al., 2020.

Genomics has aided in the promotion of a larger range of pedigrees by allowing more testing and selection of the best individuals rather than families, as well as by providing more expansive breeding goals, with increased emphasis on health, reproduction, and additional new traits that are difficult to measure and evaluate using traditional methods and reproductive traits. However, it is still common for a few elite related individuals to contribute the most to future generations. It does not take much detective work to see that most bulls on the top lists are related, but that does not mean relatedness cannot be managed.

▪ Consequences of Inbreeding

There is still a lot to learn about the impacts of inbreeding and there is no set limit for how much inbreeding is acceptable or when major issues are likely to occur. Inbreeding can elicit a variety of responses. In general, we know that the buildup of inbreeding in dairy cow herds has unfavourable consequences. That being said, any kind of direct selection will result in inbreeding, so it will not go away any time soon.

Lowered performance due to inbreeding, known as inbreeding depression, often has the greatest influence on fitness characteristics, leading to decreased fertility or health, although production can also be reduced. The impacts of inbreeding can be minor or serious, and in severely inbred animals, can result in large economic losses.

While inbreeding does not result in the creation of unwanted alleles, it does raise the likelihood that an animal may acquire two copies of the same unfavourable allele of a gene, which will be expressed in its homozygous form. Genomics has enabled the discovery of multiple recessive haplotypes. These haplotypes are genomic regions on the same chromosome carrying the recessive alleles with significant impact on economically important traits. The knowledge of these haplotypes can assist in the avoidance of mating of two carriers. Advances in genomics have also brought further insight into how we can detect these problems and can help to describe inbreeding and its varied repercussions. While pedigree-based inbreeding is based on expectations and average probabilities and is limited by pedigree depth, genomic inbreeding gives a more precise look at realized inbreeding or homozygosity at the genome level.

Inbreeding is not always harmful. In fact, the genetic gain we have seen in economically important traits has been the result of controlled inbreeding over many generations. As more genomic information becomes available, researchers are now finding specific regions of the genome where inbreeding has an impact on performance in various traits. This type of research could lead to more advanced breeding practices.

▪ Managing Diversity

Directional selection increases uniformity for desirable traits, but by increasing uniformity in general, there can be a negative consequence of reducing diversity for fitness traits. Inbreeding in a purebred population is largely unavoidable, but it can and should be managed. Inbreeding does not pass down to progeny in the same way that genes do, so an inbreeding coefficient of a potential bull does not tell you much about the inbreeding coefficient of that bull’s offspring.

When a bull with a high inbreeding coefficient is mated with a distantly related female who is not closely related to him, the resulting calves will not be highly inbred. If that same bull is mated with a highly related female, its progeny will have a high inbreeding coefficient. It is important to keep track of pedigree information to avoid accidental mating between close relatives. This can be done, for example, by maintaining good records and registering your herd with a breed association, such as Holstein Canada, who will keep track of the pedigree information for you.

When considering which bull to use on your farm, the relationship-value (R-value) is a more relevant piece of information for the breeder than is the inbreeding coefficient of the bull, since the R-value represents the percentage of DNA the bull shares with active females of the same breed. A critical component of inbreeding management is to identify each animal accurately, to establish the correct sire and dam, and to keep the overall pedigree integrity. Selecting bulls with lower R-values maintains a higher level of diversity within the breed as a whole.

As mentioned earlier, registration also makes it possible to track the herd’s pedigree, and therefore its inbreeding rate. The cost of registration is approximately $2.80/cow/year, which includes registration cost and Holstein Canada and provincial membership fees (Info Holstein, 2021. Underestimating the inbreeding rate by 1% can result in a loss of income of $9.60 per cow per year due to inbreeding depression (Holstein Canada, 2021), so it pays to keep track of your inbreeding rates.

Breeding decisions can be made in a way that considers the progeny's inbreeding level to help manage inbreeding at the farm level. Lactanet provides breeders with several tools, such as the inbreeding calculator on the website, to analyze the inbreeding level of the resulting progeny from mating different females in their herd to various sires (see https://lactanet.ca/en/genetic-evaluations/inbreeding-calculator/). Matings that produce offspring with an inbreeding coefficient higher than a given threshold can be avoided in this way. There is a point where sacrificing some genetic gain is required to preserve genetic diversity of the breed as a whole, and to decrease inbreeding at the farm level.

▪ From Genotypes to Phenotypes

In the age of genomic selection, the ability to identify exact regions of DNA that affect a particular trait is improving. The genome-wide association study is a tool used frequently in the past decade to identify and map SNP and haplotypes with a significant effect on a given trait. These studies can be used to find ‘good alleles’ and also recessive alleles of genes that cause problems when two copies are inherited, one from each parent (in this case, an animal is “homozygous” for a specific recessive haplotype). With the increased use of young genomic bulls, some of these recessive haplotypes may arise and spread throughout the population very rapidly.

In Holsteins, the recently identified haplotype for cholesterol deficiency (HCD) provides a first-class example of the danger of haplotypes containing a deleterious mutation in homozygous form. Animals heterozygous for HCD (heterozygous = the animals carry two different haplotype versions) have a reduced amount of cholesterol in their blood, but homozygote HCD animals (those that receive two identical copies of the same, detrimental haplotype) have no cholesterol and only survive a few months (Kipp et al., 2015). The defective haplotype is difficult to track because a neutral version and a recently mutated version are both very frequent, and the available SNP surrounding the mutation are identical. Other harmful haplotypes, often referred to as haplotypes affecting fertility, have been found in Holstein, Jersey, Brown Swiss, and Ayrshire animals. There are likely many more detrimental haplotypes in dairy cattle; however, they are yet to be identified. Genomic information can help track down these recessive haplotypes quickly.

Similarly, the capacity to detect lengthy segments of homozygous DNA (known as 'runs of homozygosity,' or ROH) and connect such areas with traits of interest is also increasing rapidly (e.g., Howard et al., 2017). Such studies will aid in determining whether areas of the genome have a detrimental or positive influence on characteristics of interest when ROH are present. Figure 3 shows homozygous areas on bovine chromosome 11 that influence several calving and fertility traits. Some areas are related to a variety of traits impacting calving and fertility in both heifers and first parity cows. These areas can now be identified and further investigated with more powerful analyses to find the specific causal mutations.

Figure 3. Location of runs of homozygosity (ROH) on chromosome 11 with an effect on various fertility traits. Lines represent traits as follows (from top to bottom: ac0 & ac1 = age at calving (heifer & 1st parity, respectively); afs0 = age at first service (heifer); ctfs1 = calving to first service (1st parity); cz0 & cz1 = calf size (heifer & 1st parity, respectively); do1 = days open (1st parity); fstc0 & fstc1 = first service to calving (heifer & 1st parity, respectively); gl0 & gl1 = gestation length (heifer & 1st parity, respectively); ns0 & ns1 = number of services (heifer & 1st parity, respectively); sb0 & sb1 = still birth (heifer & 1st parity, respectively) (Makanjuola et al., 2020)

▪ Conclusions

New technologies, both those applied to studying the molecular basis of inheritance, and those used to measure various physical characteristics of animals, have had, and will continue to have, disruptive effects on livestock breeding practices. Advances in technologies are being made at an unprecedented rate and large-scale implementation of these technologies will affect both genetic diversity of future livestock populations and the economics of genetic improvement. Furthermore, with active, information-seeking consumers entering the marketplace, past breeding goals centred on production may no longer be attractive and new phenotypes will need to be collected on a large scale. The implications of increasing the use of reproductive and genomic technologies and applying novel technologies and methods in livestock breeding populations must be carefully considered. In particular, the effects on genetic diversity of livestock populations, the financial implications for all stakeholders, and the societal acceptance of these technologies and their wide-spread use must be evaluated. Despite these caveats, the use of these technologies, together with their integration in breeding, could contribute to sustainable and further genomic improvement if properly managed.

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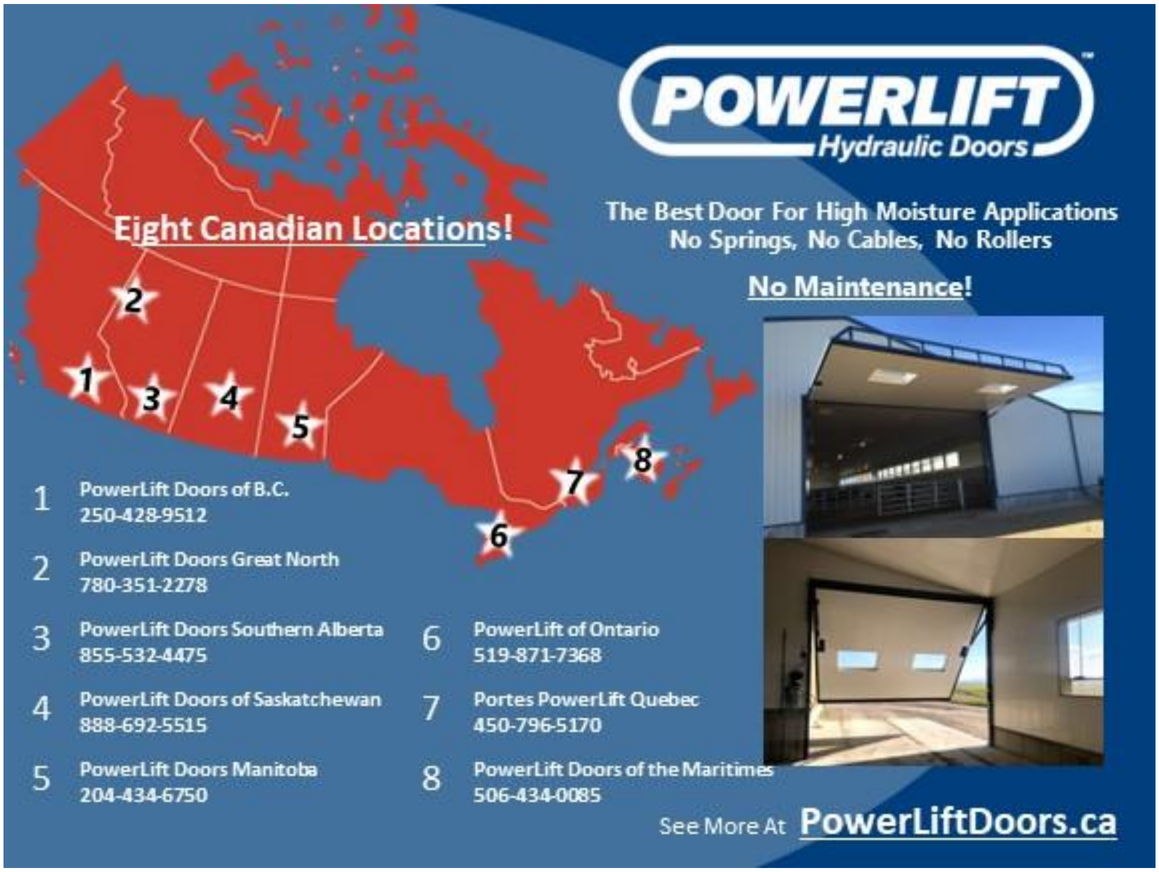
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How Can Automation be Used to Optimize Cow Nutrition?

Trevor J. DeVries

Department of Animal Biosciences, University of Guelph, 50 Stone Road East, Guelph, Ontario, N1G 2W1, Canada
Email: tdevries@uoguelph.ca

Take Home Messages

- Automated technologies are being increasingly adopted within the dairy industry to not only reduce human labour requirements, but to also increase the accuracy and precision of application of various management tasks.
- Various forms of feeding technologies are currently available to increase our ability to optimize the nutrition of dairy cows.
- At a herd level, technology can be used to monitor feed ingredients and mixing protocols, and to automate diet preparation, delivery, and push-up.
- At a cow level, there are opportunities to meet individual cow nutritional needs through individualized supplementation, particularly in association with robotic milking.

Introduction

There is much recent discussion regarding precision dairy cattle management, which can be defined as automation using sensor-based management tools that define animal needs, and robotic equipment that automatically delivers individual animal and herd management applications. Much of this stems from the current rapid development, introduction, and refinement of various forms of automation in the dairy industry. Probably the best example here in Canada is robotic (automated) milking, which continues to be adopted widely within the industry. Automation is also available and being used for health management, reproductive management, barn cleaning, ventilation, bedding, and nutrition and feeding management.

Much of the draw to adopt automation relates to the current availability and cost of labour. Beyond that, there are also benefits to the cows themselves, with the adoption of technologies that allow for greater accuracy and precision in their deployment than that traditionally realized. For dairy cow nutritional management, at a herd level, automation can reduce the variability in the composition of the diets we provide, the composition of the diets consumed by the cows, and the timing of that consumption. Further, at a cow level, automation (particularly through robotic milking) can potentially be used to accurately and precisely meet the nutritional needs of individual cows throughout lactation.

Automation to Improve Ration Accuracy and Precision

The goal of any nutritional program for dairy cows should be to meet the basic nutrient requirements for maintenance, while optimizing supply of nutrients for health and production. This should be done as accurately as possible to minimize the risk of shortchanging nutrients supplied (and thus not meeting production targets) or oversupplying nutrients (resulting in poor efficiency and waste). Despite our best efforts on these fronts, the delivered ration on many dairy farms does not accurately match that which was formulated for the cows.

As the variability between the ration offered to the cows and the original formulated ration becomes greater, so does the chance that cows will not perform to expectation. In a study by Sova et al. (2014) we sampled the mixed and delivered total mixed ration (TMR) for 22 free-stall, parlour-milked herds for seven consecutive days both in summer and winter. The nutrient analysis of these feed samples was then compared to that formulated for those farms. Across farms, the average TMR fed did not accurately represent that formulated by the nutritionist. The average TMR delivered exceeded TMR formulation for net energy of lactation (NE_L), non-fibre carbohydrate (NFC), acid detergent fibre (ADF), calcium, phosphorus, magnesium and potassium, and underfed crude protein (CP), neutral detergent fibre (NDF) and sodium. Across farms, however, there was a huge range in this variation, with some farms consistently experiencing a 5–10% discrepancy (both positive and negative) between the fed and formulated ration for nearly all nutrients. Theoretically, overfeeding might not be problematic because a safety margin is generally included in formulation to account for uncertainty in ingredient composition. However, excessive overfeeding can result in waste and decreased efficiency, while underfeeding could lead to production targets not being met.

Similar deviations in diet accuracy were observed in a study by Trillo et al. (2016) of 26 California dairies (ranging in size from 1,100 to 6,900 cows) throughout a 12-month observation period. Those researchers observed that the median deviation for high cow production recipe was below the target weight on 10 dairies or above the target weight on 16 dairies. Further, they observed that the absolute deviation from target was more than 2% at least 50% of the time on seven of those dairies. As result of these deviations from the target weight, those researchers demonstrated that the cost of high cow production recipe increased in many dairies on many days, was decreased in lesser cases, and was only consistent to the target cost in very few instances. Those researchers concluded that these deviations from target were partly influenced by ingredient type, with certain ingredients being more consistently loaded with poor accuracy and precision.

In addition to challenges with diet accuracy, there are probably even greater challenges with diet precision, that is, providing the same diet day in, day out. In the study by Sova et al. (2014), we investigated the day-to-day consistency in physical and chemical composition of TMR and associations of that variability with measures of productivity. Greatest day-to-day variability was observed for refusal rate, particle size distribution, and trace mineral content. Delivery of a more consistent ration was associated with improved production. For example, greater dry matter intake (DMI; Figure 1a), milk yield (Figure 1b), and efficiency of milk production (Figure 1c) were all associated with less daily variability in energy content of the ration (Sova et al., 2014). Lower daily variability in the percentage of long forage particles in the offered TMR was associated with greater milk yield and efficiency of milk production. On average, day-to-day variability was greater for physical characteristics (i.e., particle size distribution) of the ration compared with the ration's nutritional composition.

Deviations in diet accuracy and precision are largely going to be influenced by variability in feed ingredients and possibly even more so by mixing errors associated with operators (timing, sequencing) or equipment. This suggests that increased surveillance of the TMR composition, in addition to individual feed ingredients (e.g., regular, frequent forage DM determination, regular nutrient testing of feeds) are helpful as a regular component of feeding management to ensure delivery of TMR with the intended nutrient composition to maintain production and feed intake. Of that, probably the biggest contributor to feed ingredient variability would be lack of knowledge of feed dry matter (DM), particularly that of ensiled forages. Often DM content is not measured frequently enough due to the time and labor required to do so. Using technology (for example, NIR sensors on feed loading/mixing equipment) can help with that. Further, having proper protocols in place (and training for those), and monitoring of that through feed management software may be important for minimizing that risk of variation. Finally, probably the biggest opportunity the industry has to reduce variability is to lessen the amount of human operated equipment in the feeding process and employ more automation therein. To that end, the adoption of automated feed (TMR) preparation and mixing equipment is expected to increase, along with improvements to those technologies.

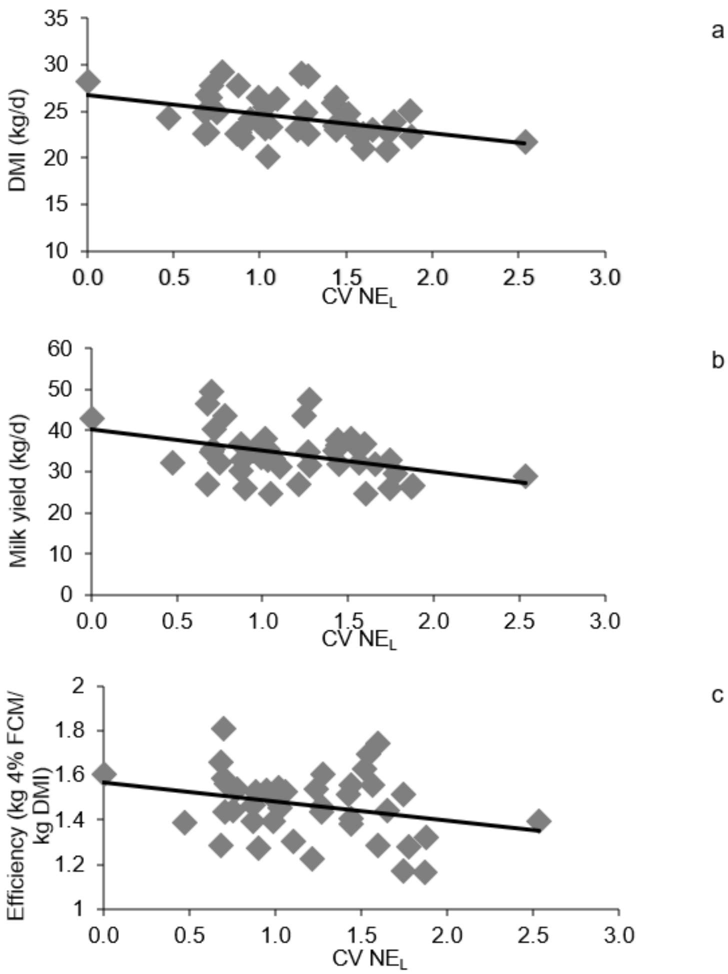

Figure 1. Association between fed ration coefficient of variation (CV) in NE_L and average a) DMI, b) milk yield, and c) feed efficiency. Coefficient of variation was calculated as the standard deviation of NE_L over 7 d divided by the average NE_L over 7 d. Figure adapted from Sova et al. (2014).

▪ Automation to Optimize Cow Eating Behavior

Even if we get the TMR right and deliver it as formulated on a consistent basis, it does not mean cows will eat that ration as distributed to them or in a manner that is good for them. Because changes in DMI must ultimately be mediated by changes in feeding behaviour, and that behaviour can also influence rumen health and efficiency, it is important to understand the factors that influence cow feeding behaviour patterns.

Total mixed rations are designed as homogenous mixtures with the goal to minimize the selective consumption of individual feed components by dairy cattle and promote consistent intake of a complete diet. Despite this, dairy cattle have been shown to preferentially select (sort) for the grain component of a TMR and discriminate against the longer forage components. The sorting of TMR by dairy cows can result in the ration actually consumed by cows being greater in fermentable carbohydrates than intended and lesser in effective fibre, thereby increasing the risk of depressed rumen pH (Miller-Cushon and DeVries, 2017a; DeVries, 2019). Likely related to this, sorting of a TMR has been associated in several of our studies with cows producing milk with lower fat percentage (DeVries et al., 2011a; Fish and DeVries, 2012; Miller-Cushon and DeVries; 2017b).

Imbalanced nutrient intake as a result of sorting also has the potential to impact the efficiency of digestion and production. In support of this, Sova et al. (2013) demonstrated that efficiency of milk production decreased by 3% for every 1% of group-level selective over-consumption (sorting) of fine ration particles. We also demonstrated in that study that every 2-percentage point increase in selective refusal (i.e., sorting against) of long ration particles on a group level was associated with a per cow reduction of 0.9 kg/d of 4% fat-corrected milk.

It is important to not only consider what dairy cows actually consume from their provided ration, but also the manner in which the ration is consumed. Intensively housed dairy cattle fed a TMR typically consume their daily DMI in up to 6 hours/day, spread between seven or more meals per day (DeVries et al., 2003). When cows have more frequent, smaller meals throughout the day and eat more slowly, rumen buffering is maximized, large within-day depressions in pH are avoided, and the risk of sub-acute ruminal acidosis is decreased (DeVries, 2019). These improvements in the rumen environment may also translate into improved DMI. In recent research we demonstrated, using data from multiple studies of high production cows, that both meal frequency and total feeding time were stronger predictors of daily DMI, and subsequently milk yield, than the size of meals consumed or the speed at which they were consumed (Johnston and DeVries, 2018). Thus, to promote consistency in consumption and digestion, it is important to use rations, management, and housing that promote the frequent consumption of feed in small meals, spread over a longer period of time at the feed bunk.

One method to achieve that type of feeding behaviour is to increase the frequency of feed delivery (DeVries et al., 2005). Greater frequency of TMR delivery has been associated with greater DMI (Sova et al., 2013; Hart et al., 2014) Further, delivering a TMR 2x/day or more often reduces the amount of feed sorting compared with feeding 1x/d (DeVries et al., 2005; Endres and Espejo, 2010; Sova et al., 2013), which would further contribute to more consistent nutrient intakes over the course of the day. Such desirable feeding patterns are conducive to more consistent rumen pH, which likely contributes to improved milk fat (Rottman et al., 2014). In support of that, Woolpert et al. (2017) reported that dairy herds with high de novo fatty acid (FA) concentration in bulk tank milk, compared with those with low de novo FA concentration, tended to be 5x more likely to be fed 2x versus 1x per day, confirming the positive impacts of feeding >1x/day on maintaining a consistent rumen environment. Similarly, Castro et al. (2022) demonstrated in a study of 124 automated (robotic) milking system (AMS) farms that greater frequency of partial mixed ration (PMR) delivery (>2×/day vs. 1 and 2×/day) was positively associated with a greater proportion (g/100 g of FA) of de novo FA in the bulk tank milk of those farms.

Clearly there are benefits to delivering feed (i.e., TMR or partial mixed ration (PMR)) more often per day. Practically, implementation of greater TMR delivery frequency on dairies is often constrained by time and cost associated with TMR preparation and its delivery. Thus, implementation of feeding automation, not only for diet preparation, but also for frequent delivery to cows across the day may have significant benefits in terms of achieving greater precision. Automated TMR delivery systems (e.g., autonomous, rail, or conveyor) are available for use within the industry, allowing for high feed delivery frequencies without additional labour needed. There is, however, a paucity in research on the effectiveness of the implementation of these automated TMR mixing and delivery systems.

TMR push-up is also critical to ensure that feed is accessible when cows want to eat. Feed push-up needs to occur frequently enough such that any time a cow decides to go to the feed bunk, there is feed available to her. Feed push-up also helps minimize variation in feed consumed because it mixes up the feed that is no longer in reach with that which is currently available in the bunk. Thus, frequent pushing up of TMR in the bunk is necessary, particularly in the first few hours after feed delivery, when the bulk of the feeding activity has occurred. We have demonstrated that greater lying duration is associated with greater frequency of feed push-ups (Deming et al., 2013; King et al., 2016), suggesting that frequent push-up minimizes the time cows need to spend waiting for feed access and cows can devote more time to lying down. More frequent feed push-up may be particularly beneficial for robotic milking systems, where voluntary milkings are often centred around times of feeding activity at the bunk (DeVries et al., 2011b).

Feed push-up will also ensure that DMI is not limited and, thus, production is optimized. Evidence for this was shown in a cross-sectional study of 47 herds, all with similar genetics and feeding the exact same TMR (Bach et al., 2008). In that study it was reported that those herds where feed was not pushed up (5 out of

47 herds) produced 3.9 kg/d/cow less milk (-13% difference) than herds where feed was pushed up. Siewert et al. (2018) reported that robot farms with automatic feed push-up produced 352 kg more milk/robotic unit and 4.9 kg more milk/cow per day than farms that manually pushed up feed. In a more recent study by our group (Matson et al., 2021), we demonstrated in an observational study of 197 Canadian robot milking farms, that each additional 5 feed push-ups per day was associated with 0.35 kg/d/cow greater milk yield. Interestingly, given the mean push-up frequency between those that pushed up feed manually (4.4 times per day; 19% of farms) and those that used a robotic feed pusher (16.8 times per day; 71% of farms) in our study, it is likely that our findings and that of Siewert et al. (2018) were driven by the frequency feed was pushed up within each system, rather than by the method itself. More specifically, these effects may not be directly attributable to the use of an automated feed pusher, but rather that those farms using such automated equipment had more consistent feed push-up, and thus continuous feed access, than those pushing up feed manually. In situations where manual feed push-up is done consistently and frequently, the same results should be achievable. Unfortunately, in reality, manual feed push-up, performed by farm staff, is more prone to inconsistency, in time and frequency, and many farms lack the required labour needed to do so; thus, this again provides support for the use of this type of automation.

▪ Automation to Meet Individual Cow Requirements

Along with herd-level nutrition precision achieved through automation, there is also opportunity to use automation to achieve that precision at an individual animal level. The rapid adoption of technologies that allow for individualized feeding, including automated milking and calf feeding systems, has also increased our potential ability to feed cattle according to their individual requirements.

As we have the ability to supplement the feed consumption of dairy cows within AMS, there is potential for applying some type of precision feeding approach in AMS (Bach and Cabrera, 2017). While there is potential, there are also several challenges with such an approach. In AMS, the herd is fed a common diet (PMR) at the feed bunk. As this PMR diet is static, the ‘precision’ aspect, to meet individual cow nutrient needs, would need to be accomplished with the feed provided at the AMS. In theory, if the individual nutrient requirements were known (based on expected milk production, and other known factors including age, body weight, stage of lactation, pregnancy status) then the amount of feed provided in the AMS could be adjusted to the cow’s individual need. The challenge with that is being able to accurately predict the nutrient consumption from the PMR, as that is not measurable on an individual basis in commercial settings. Therein lies the difficulty. It has been demonstrated that the level of PMR consumption is affected by the level of concentrate provided at the AMS, and it is not necessarily an even substitution ratio (Hare et al., 2018; Menajovsky et al., 2018; Paddick et al., 2019; Schwanke et al., 2019; Schwanke et al., 2022). In fact, across studies, the substitution ratio (amount of decrease in PMR intake for every 1 kg increase in AMS pellet intake) has ranged from 0.54 to 1.58 kg (Hare et al., 2018; Schwanke et al., 2022). As such, it may be difficult to predict total DMI, and thus total nutrient intake, when varying the amount of feed provided at the AMS, making precision feeding more difficult. Further, in studies where we have increased the quantity of AMS pellet offered in the AMS, the day-to-day variability in the consumption of the AMS pellet also increased (Hare et al., 2018; Menajovsky et al., 2018; Paddick et al., 2019; Schwanke et al., 2019). This variation then makes the concept of precision more difficult to attain. A further challenge with feeding in AMS is that just because cows are provided feed at the AMS, does not guarantee they will consume it (Bach and Cabrera, 2017). Any unconsumed feed left in the AMS results in another cow potentially consuming more than what she is programmed for; this reduces the ability to precision feed these animals.

While most AMS are only equipped with a single bin for delivering concentrate to cows (Bach and Cabrera, 2017), there is opportunity within many systems to provide multiple feeds. It’s possible that greater precision in feeding could be achieved in such scenarios, as the amount and balance of different types of supplement feeds could be used to match individual cow nutrient requirements. To date, however, there is limited research on this type of approach. In a recent study, we demonstrated that we could improve energy balance and minimize body condition loss in early lactation by supplementing cows milked in AMS with a molasses-based liquid feed supplement in addition to their regular AMS concentrate (Moore et al., 2020).

There may be opportunities to apply such precision feeding principles in other types of milking systems. One such example is that described by Bach (2014), a ‘dynamic concentrate parlour feeder’ which involves the preparation and delivery (in real time) of many different feeds (in both quantity and composition) within a rotary milking parlour. The system calculates the individual nutritional requirements of each cow entering the parlour based on her assigned feed intake (average of the pen where she is), composition of the TMR fed, DIM, parity, BW, BW change, pregnancy status, milk yield, and milk component yields. Based on those needs, the system creates a least-cost formula using up to 6 feeds that are mixed and delivered to the cow in less than 14 seconds. Bach (2014) suggested that such a system would allow for the feeding of a more cost-effective TMR with a low nutrient density, without compromising, and even potentially improving, income over feed cost by delivering nutrients to only those cows in need of them.

One area where there has been more success in application of individualized feeding strategies is with the use of automated calf milk feeders. Automated calf feeders provide the ability to feed calves individualized milk diets that may be calf-specific based on age, weight, or any other parameter deemed appropriate. This may include altering the speed at which milk allowance is increased in early life, as well as decreased at the time of weaning. To date, however, much application of these feeding strategies, while applied at the calf level, is still done similarly across all animals within a farm. There is research to suggest that much gain can be made by tailoring feeding programs for individual calves based on their individual needs. For example, de Passille and Rushen (2016) demonstrated that individual calves differ greatly in when they begin to consume solid feed and how quickly they increase the intake in response to a decrease in milk allowance. Those researchers demonstrated that automated milk feeders could be used to wean calves at variable ages, depending on their ability and willingness to eat solid feed.

▪ Conclusions

Automated technologies have been developed and increasingly adopted within the dairy industry to not only reduce human labour requirements, but also to increase the accuracy and precision of application of various management tasks. Various forms of feeding technologies are currently available to increase our precision in feeding strategies of dairy cattle to optimize nutrition. At a herd level, this includes automated feed preparation and delivery, as well as incorporation of technology in feed monitoring. At the animal level, this includes individualized feeding opportunities, to date primarily through automated milking in lactating cows and automated milk feeders in calves. While there are still many challenges associated with the successful implementation of such precision feeding strategies, on-going research would suggest that these opportunities will continue to grow, allowing for greater nutrient capture, greater efficiency, less nutrient waste, and greater health and production.

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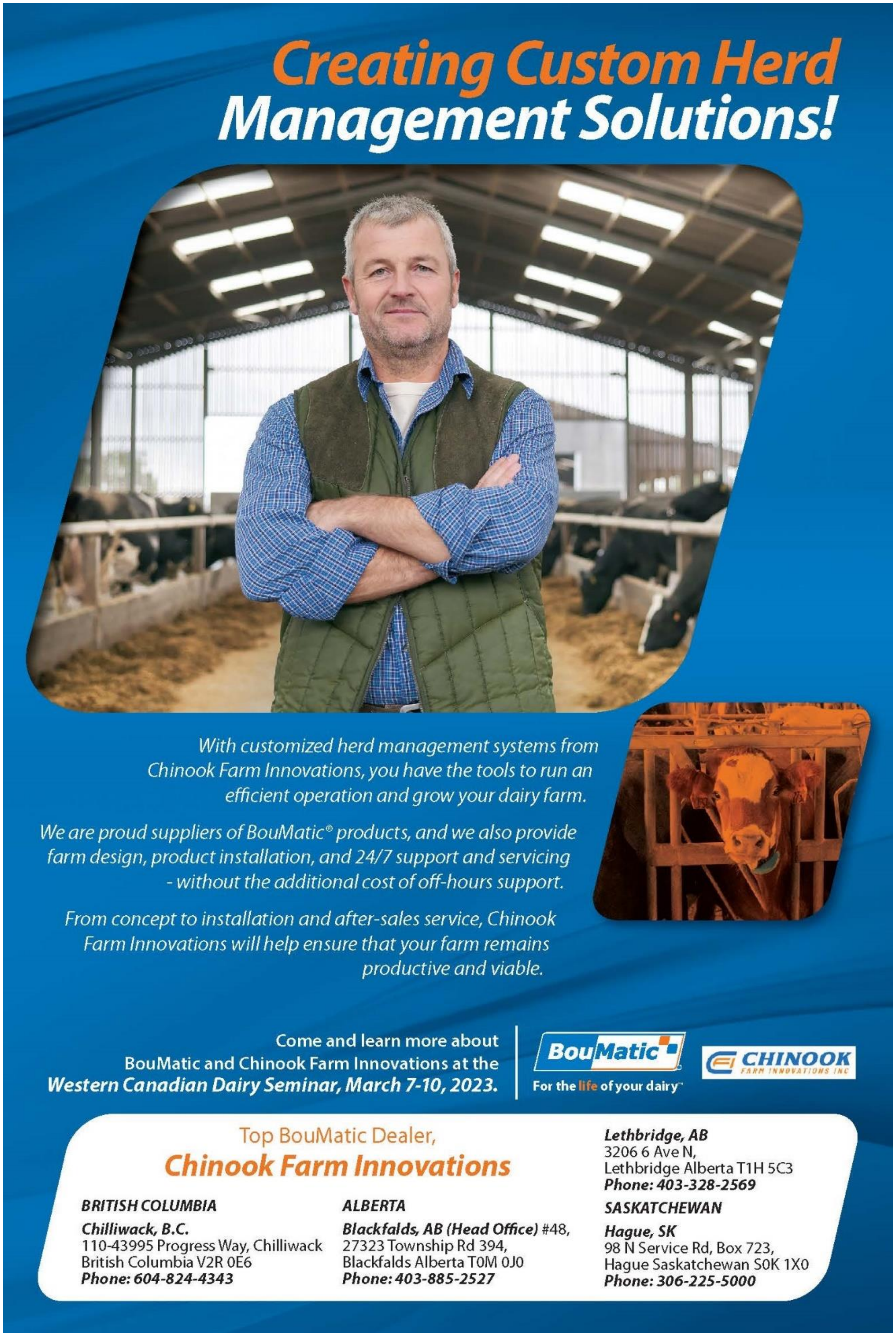
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Transition Period Health and Reproduction: Preparing for a Successful Pregnancy

Stephen LeBlanc

Population Medicine, University of Guelph, Ontario, Canada N1G 2W1
sleblanc@uoguelph.ca

Take-Home Messages

- If both clinical and subclinical conditions are comprehensively monitored, 30 to 50% of cows experience at least one disorder in the transition period, most of which are associated with impaired reproductive performance. However, healthy cows, even at high production, have good fertility.
- Avoidance of reproductive disease and loss of more than 0.5 point of body condition score are important for reproductive performance.
- Effective monitoring and treatment programs for metritis and purulent vaginal discharge can limit the consequences of these problems.

Introduction

Clinical diseases in dairy cows such as retained placenta and metritis are obvious, but subclinical disease may have greater effects on herd reproductive performance because the incidence may be greater and cases may go untreated. There is an opportunity for farmers and their advisors to assess ketosis, hypocalcemia, and subclinical reproductive disease (purulent vaginal discharge and endometritis) and put monitoring and treatment programs in place. These problems may be associated with impaired fertility for two to six months after occurrence. Ongoing management to prevent metabolic health problems supports productivity and reproduction.

Essentially all dairy cattle experience a period of insulin resistance, reduced feed intake, negative energy balance, hypocalcemia, reduced immune function, and bacterial contamination of the uterus soon before, or in the weeks after calving. A glucose deficit, hypocalcemia, mobilization of body fat, ketosis, and systemic inflammation influence immune response in transition cows and all these change rapidly and vary substantially between cows.

Links between postpartum disease and fertility are well established. The consequences of difficult calving, milk fever, and displaced abomasum are immediate and obvious. However, other less obvious problems may have greater effects on herd reproductive performance because they affect greater proportions of cows and may go undetected and untreated.

A dataset on nearly 6000 cows from seven large, high-production herds in the U.S. illustrates the prevalence and health disorders in the transition period and their associated consequences for reproduction (Santos et al., 2010). Unsurprisingly, each of dystocia, metritis, endometritis, ketosis, and lameness was associated with reduced probability of pregnancy at first insemination. The sobering statistic was that, when disease was comprehensively monitored, only 56% of cows got through the transition period without at least one clinical or subclinical condition. On the other hand, healthy cows had excellent fertility, with 51% pregnant at first service, and had fewer pregnancy losses than did cows that experienced health problems, notwithstanding high production (average 305 d milk yield was ~ 11,000 kg). Additional studies using large datasets form single herds confirmed these associations and underlined the additive negative effects of having more than one clinical disease on pregnancy rates (Carvalho et al., 2019; Pascottini et al., 2020).

These incidence rates are expected considering both clinical diseases (i.e., visible, obvious conditions such as retained placenta) and subclinical conditions for which routine examination or testing is required, such as ketosis and purulent vaginal discharge (PVD). For example, weekly or semi-weekly screening for ketosis in the first two weeks postpartum reveals that on average, 40% of cows experience ketosis (McArt et al., 2012; Gordon et al., 2017). When examined routinely once at four to five weeks postpartum, 5 to 20% of cows have PVD and 15 to 30% have subclinical endometritis (deBoer et al., 2014; Dubuc and Denis-Robichaud, 2017)

Cows with ketosis (blood beta-hydroxybutyrate (BHB) > 1.2 mmol/L) in both of the first two weeks postpartum had lower pregnancy rates at first artificial insemination (AI) than healthy cows, and cows with ketosis in either of the first two weeks had reduced pregnancy rates until ~ 165 days in milk (DIM; Walsh et al., 2007). Recent data (Rodriguez et al., 2021) refined the association by showing that ketotic cows in the lowest within-herd quartile of milk yield in the first week of lactation had substantially worse pregnancy rates, but cows with middle or top quartile milk yield had equally good pregnancy rates whether ketotic or not.

Many studies have consistently shown that cows with pus discharge (PVD) at four to six weeks postpartum have reduced probability of pregnancy at first AI (~15 to 25%) and take 20 to 30 days longer for half to become pregnant than healthy cows. Similarly, cows with chronic, low-grade uterine inflammation (endometritis diagnosed by uterine cytology) have median time to pregnancy 30 to 40 days longer than healthy cows. For details, see a systematic review by DeBoer et al. (2014).

It is clear that ketosis, PVD, and endometritis may have substantial harmful effects on the affected individual cows. An economic model (McArt et al., 2015) indicated that overall, herds with at least 15% of cows that experience ketosis would profit from a systematic test-and-treat program. A study of 17 herds in Ontario and Michigan found that all had ≥ 15% of cows with ketosis (Gordon et al., 2017), but some herds have a lower cumulative incidence (e.g., Rodriguez et al., 2021). A study of 126 farms in Quebec (Dubuc et Denis-Robichaud, 2017) helps to inform herd-level decisions about investing time and money in transition period monitoring programs to improve reproductive performance. The study estimated the prevalence of health conditions related to reproduction and their association with herd-level pregnancy at first insemination and with pregnancy losses from 30 to 60 days of gestation. The results are summarized in Table 1. The researchers identified thresholds of prevalence of health problems that were associated with pregnancy at first service below the top quartile in the sample of herds or with > 5% pregnancy loss. These data underline the importance of measuring the prevalence of these conditions in all herds, and suggest that where these exceed these levels, it is probably worth investing effort in prevention, detection, and treatment.

Table 1. Thresholds of prevalence of health conditions associated with reduced herd-level reproductive performance (from Dubuc and Denis-Robichaud, 2017)

Prevalence or Incidence (estimated from a sample of 20 cows per herd)	Threshold Associated With	
	First service probability of pregnancy < 40%	Pregnancy loss from 30 to 60 days > 5%
Retained placenta	-	≥ 5%
Ketosis*	≥ 12%	-
Displaced abomasum	≥ 4%	-
PVD at one month postpartum	≥ 5%	≥ 5%
Endometritis (uterine cytology examination)	≥ 19%	-
Anovulation (blood progesterone measured at 30-44 and 44-57 DIM)	≥ 21%	-

* Ketosis was measured only once per cow between one and 14 DIM, which is expected to underestimate the prevalence by approximately half; DIM = days in milk.

Figure 1 illustrates patterns seen in several large studies of the effects of uterine and non-uterine disease on reproduction. Cows with inflammatory disease are 5 to 15% points less likely to be pregnant to the first breeding and 5 to 10% points more likely to lose the pregnancy after diagnosis ≥ 30 days. Having more than one disease is worse than having a single clinical condition.

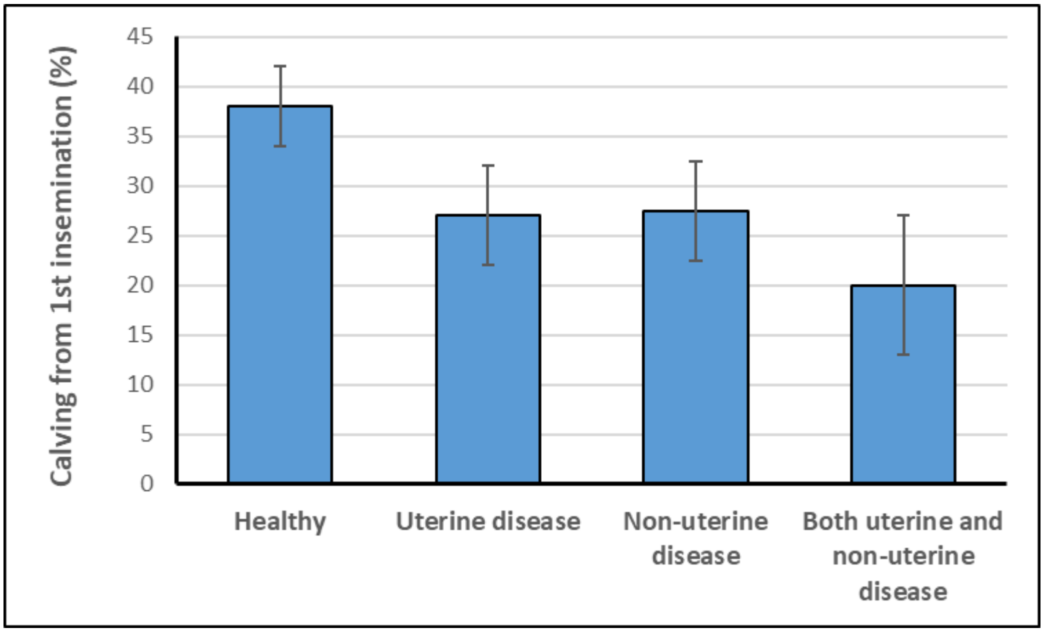

Figure 1. Associations of disease in the transition period with the probability of successful full-term pregnancy (mean and 95% confidence interval; data from 4476 cows; re-drawn from Ribeiro and Carvalho, 2017).

▪ Mechanisms Linking Heath and Reproduction

It makes intuitive sense that cows that experienced disease in the transition period have impaired reproductive performance. However, the mechanisms that connect transition disease to expression of estrus, pregnancy, and pregnancy losses at least one month to six or more months later are complex. These include:

- Final development of follicles from microscopic primary stages to a potentially ovulatory stage takes two to four months, so follicles ovulated for first service developed in the hormonal, energy deficit, and inflammatory environment of the postpartum period. The effects of these variables on follicle and oocyte quality are described in the "Britt hypothesis" (Britt, 1992).
- Follicular fluid and cells are exposed to endotoxin from uterine infection and inflammatory cytokines from the uterus (Bromfield et al., 2015) and affect follicular function and oocyte quality (Sheldon et al., 2019). The concentration of endotoxin in follicles was twice as great in anovular as ovular cows (Cheong et al., 2017).
- Postpartum uterine infection with recognized pathogenic bacteria was associated with reduced growth rate of the first dominant follicle, and after ovulation, with smaller corpora lutea (CL) with lesser blood progesterone concentration (Williams et al., 2007).
- Although metritis was not associated with anovulation (Ribeiro and Carvalho, 2017), endometritis in week five was associated with 1.5 times greater odds of anovulation at week nine postpartum (Dubuc et al., 2012).
- Cows that had metritis or another inflammatory condition postpartum were less likely to be pregnant and had fewer and lower quality embryos when flushed after first insemination (Gilbert, 2011; Ribeiro and Carvalho, 2017). Subclinical endometritis at the start of superovulation in donor cows reduced the number of transferable embryos by more than half (Carvalho et al., 2013).

- Embryos that were exposed to endotoxin in vitro (Magata and Shimizu, 2017) or to experimentally induced sterile inflammation in the cow (Hill and Gilbert, 2008) had reduced quality.

The interactions among these mechanisms and how they affect fertility was recently reviewed (Gilbert, 2019). Current understanding of this pathophysiology leads to the concept that it is important to have a rapid, robust, effective immune response immediately after calving, followed by regulation of inflammation that allows for return to normal reproductive function. Figure 2 illustrates the factors that contribute to this challenge.

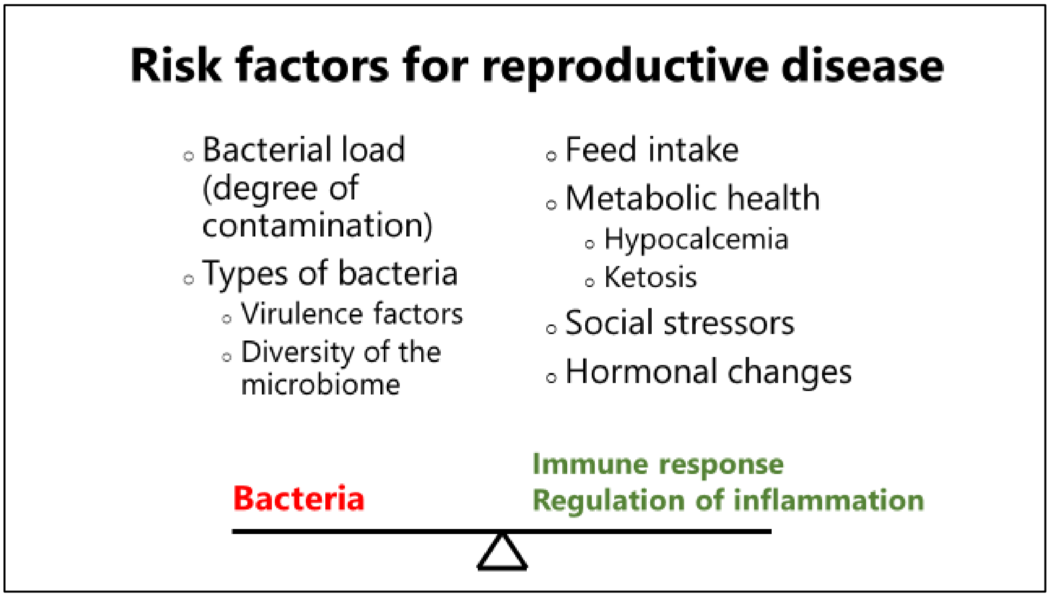

Figure 2. Risk factors for reproductive disease, which results from an imbalance between the load of bacterial pathogens and variables that support or impair effective and well-regulated response.

Adaptation or Maladaptation to Negative Energy Balance: NEFA and Ketosis

Cows must mobilize body fat and lose weight to support lactation. Increased blood concentrations of non-esterified fatty acids (NEFA; a marker of mobilization of fat) and ketones (notably BHB), a marker of oxidation of fatty acids) is part of the normal physiologic adaptation to lactation. However, if the amount or rate of fat mobilization exceeds the capacity of the liver to oxidize these fatty acids, the situation can become maladaptive, leading to increased risk of clinical disease.

Two indicators of adaptation to negative energy balance, NEFA and BHB, are associated with several aspects of immune function and systemic inflammation (Ingvartsen and Moyes, 2013; Pascottini and LeBlanc, 2020; LeBlanc 2020). About 35% of postpartum cows experience NEFA concentrations and 45% BHB concentrations above thresholds associated with increased risk of clinical disease, reduced milk yield, or impaired reproduction (McArt et al., 2013). Serum NEFA > 0.4 mmol/L in the ten days before calving is associated with increased risk of retained placenta, culling before 60 DIM, and reduced milk yield in the first four months of lactation. Subclinical ketosis (serum BHB ≥ 1.2 mmol/L) in the first or second week postpartum is associated with increased risk of metritis, endometritis, prolonged postpartum anovulation, and if onset is within five DIM, a reduction in milk yield in early lactation.

A detailed economic model (McArt et al., 2014) showed that a routine test-and-treat program for ketosis at least once in the first two weeks postpartum was profitable for herds with a cumulative incidence of ketosis (the proportion of cows that test positive at least once in the first two weeks) between 15 and 50%. That represents the majority of herds. The optimum program tests cows twice weekly between three and ten DIM. However, weekly testing is a good starting point.

Based on the results of two large randomized controlled trials (Gordon et al., 2017a,b) using cure of ketosis and milk yield in early lactation as endpoints, we recommend the following for treatment of ketosis:

- If blood BHB ≥ 1.2 but < 2.4 mmol (approximated by milk BHB of 100 μmol/L):
  - Treat with 300 g propylene glycol orally for 3 days
- If blood BHB ≥ 2.4 mmol/L (milk BHB of approximately 200 μmol/L):
  - Treat with 300 g propylene glycol orally for 5 days
- If blood BHB ≥ 1.2 mmol/L and blood glucose < 2.2 mmol/L (expected in 35 to 40% of ketotic cows):
  - Add injection of 25 ml Catosal or 1.25 mg vitamin B12 SC daily for 3 days
- Repeat testing after the final treatment. If blood BHB still ≥ 1.2 mmol/L, continue treatment with propylene glycol for 3 more days, once.
- Recent large studies do not support additional treatment with dexamethasone (Tatone et al., 2016) or IV dextrose (Capel et al., 2021).
- Once-a-day milking improved resolution of ketosis (Williamson et al., 2021) but the optimal duration of reduced milking frequency requires further study. In this trial, 14 days of 1X vs. 2X milking substantially improved cure of ketosis, especially in cows in first lactation, but milk yield was reduced through most of the lactation.

Herd Management to Support Health and Fertility

There are few validated nutritional or management tactics specifically to reduce reproductive disease or to improve reproductive performance. The aims are to support metabolic adaptation and innate immune function, thereby reducing the odds that inevitable inflammation and bacterial contamination of the uterus develop into disease. Excessive negative energy balance and fat mobilization (of which NEFA and BHB are markers), and prolonged insulin resistance contribute to systemic inflammation (Bradford et al., 2015) which may impair uterine and ovarian health (Gilbert, 2019). There is a healthy debate about whether systemic inflammation is a cause or a consequence of metabolic maladaptation, and how to define the latter (Horst et al., 2021). Practically, the goals remain to support metabolic health, immune function, and a regulated inflammatory state. A key element is to maintain feed intake around calving with a rapid increase afterwards. Although there is still much to be learned about the determinants of metabolic health and reproduction in dairy cows, best management practices for the transition period should minimize postpartum reproductive disease. These are summarized in Table 2.

Table 2. Recommended practices for management and monitoring of dairy cows in the transition period

Management

- Feed daily with 5% weighbacks
- Provide sufficient feeding space to minimize competition (≥ 30" (75 cm) per cow or no more than 4 cows per 5 headlocks). Therefore, design transition pens for ~ 130% of the expected monthly average number of calvings.
- ≤ 85% freestall stocking density
- 130 ft^2 (12 m^2) of bedded pack/cow
- Stalls sized and bedded for cow comfort; heifers exposed to freestalls and headlocks before the transition pen.
- Fans and sprinklers when the temperature-humidity index is > 68 (~ > 25^{o}C)
- House heifers separately if it does not violate any of the above.
- Moderate BCS at calving: 3.0 to 3.5

Nutrition

- Do not exceed energy requirements in the dry period
- Provide sufficient metabolizable protein (~1100 g/d)
- Allow time for adaptation to dietary changes (3 to 4 weeks) or use single dry cow diet
- Minimize group and diet changes
    - Move cows into new groups at least 2 at a time
- Provide water ad lib: 2 sources per pen and ≥ 4" (10 cm) of linear trough space per cow
- Feed dietary vitamin E at 1000 IU in far-off and 2000 IU per cow per day in the close-up periods, and 0.3 ppm selenium (ideally ~ 6 mg/cow/day))
- DCAD ~ -100mEq/kg DM for 3 weeks before calving; target urine pH between 6.0 and 6.5
- Monensin capsules

Monitoring

- Measure dry matter intake daily
- Measure forage dry matter weekly and adjust rations accordingly
- Blood testing as needed
- NEFA < 0.4 mmol/L in the week before calving (week -1); < 1.0 mmol/L in the first week of lactation
- BHB < 0.8 mmol/L in week -1
- BHB < 1.1 mmol/L in week 1
- BHB < 1.2 mmol/L in weeks 2 and 3
- Calcium: 1st lactation cows: > 2.15 mmol/L at 1 and 2 DIM; multiparous cows: > 1.8 mmol/L at 1 DIM* and > 2.2 mmol/L at 4 DIM. *for disease risk; cows with serum calcium < 1.8 at 1 DIM but > 2.2 at 4 DIM had greater milk yield (McArt & Neves, 2020).

Conclusion

Monitoring of dairy herds should include quantitative assessment of the management and nutritional practices in Table 2, the incidence of ketosis and metritis, and the prevalence of PVD. These data will inform the development of herd-specific plans and decisions about routine testing programs. Armed with these data, advisors and producers can identify potential problems and opportunities to support success at first insemination.

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Fernando Hernandez 403-915-4311 fhernandez@masterfeeds.com
Wayne Kaplar 403-315-0063 wkaplar@masterfeeds.com
Hamid Khazanehei, PhD 403-437-3763 hkhazanehei@masterfeeds.com
Kyle Macor 403-795-9018 kmacor@masterfeeds.com
Mark Schokking 403-596-8582 mschokking@masterfeeds.com
Brian Tolley 587-370-7917 btolley@masterfeeds.com


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BECAUSE NUTRITION MATTERS.

What Activity Monitors Can and Cannot Do Today

R.L.A. Cerri, S. Moore, J. Marques, R. Conceição, A. Moore, A. Bega, J. Denis-Robichaud,

Applied Animal Biology, Faculty of Land and Food Systems, University of British Columbia, Canada
Email: ronaldo.cerri@ubc.ca

Take Home Messages

- More information from automated activity monitors than is currently available can be useful
  - Intensity of estrus as measured by activity monitors is closely associated with fertility. Activity monitors should be used for much more than only alerts.
  - Artificial insemination and embryo transfer can both be affected by expression of estrus and its intensity.
- Reproductive programs with strong reliance on estrous detection are highly efficient
  - Combination with timed AI is still necessary.
  - Expect more variability in the results of these programs than the results of timed AI based programs among farms.
  - An injection of GnRH at AI has significantly improved fertility, particularly for cows with low intensity estrus.
- Next Steps
  - Refine estrus-based reproduction programs
    - Selective synchronization, GnRH timing, sexed semen.
  - Improve knowledge on automated monitor algorithms and data collection
    - Addition of easy-to-use features on commercial software.
    - Fine tune intensity thresholds from activity monitors to better predict fertility and create management tools to improve herd reproductive efficiency.
  - Genetic selection
    - Collection of digital phenotypes to use in genomic evaluation (Resilient Dairy Genome Project – Genome Canada) and creation of databases.

Introduction

Recent studies have shown that actual display of estrous behaviour and the intensity of it seem to have a profound effect on fertility (Burnett et al., 2017; Madureira et al., 2018). Most of the data currently available in dairy cows on the effect of proestrus and estradiol pertains to the manipulation of the timing of luteolysis and ovulation induction, therefore modifying the proestrus. Studies that modified follicular dominance length (Cerri et al., 2009), concentrations of progesterone during diestrus (Cerri et al., 2011; Bisinotto et al., 2015), proestrus length and estradiol exposure (Mussard et al., 2003; Bridges et al., 2005) and production parameters (e.g., lactation and age; Sartori et al., 2002) have described these effects on fertilization, embryo quality and uterine environment, and reduction in pregnancy losses during the late embryonic development (Ribeiro et al., 2012). However, in spite of marked effects related with the aforementioned modifications of the estrous cycle, minimal emphasis was previously placed on the sole or additive effect of expression of estrus on reproductive tissues. The effect of estrus on fertility will be extensively discussed in this manuscript; it is clear that estrus has an important positive impact on fertility. This effect also seems to be associated with the intensity of estrus, which collectively leads us to questions regarding the physiological mechanisms associated with this improvement in fertility.

In order to answer some of these questions, a series of studies using automated activity monitors (AAM; e.g., accelerometers and pedometers) were performed by our group and others. In the first stages, there was a concern to revisit some concepts of which parameters are or are not associated with an estrus event. Also because of the massive use of AAM in recent years in parts of North America and Europe, large amounts of information around the time of estrus have become available to then correlate with actual physiological events. This manuscript will then follow a rationale that includes 1) overall association of estrus events and intensity with production parameters, 2) the consistent and significant effect of estrus on pregnancy per AI (P/AI) and pregnancy loss, 3) the possible causes for such an effect (e.g., ovulation failure, endometrium environment) and 4) estrus based reproductive program effectiveness and recent tools developed to improve its efficiency.

Production Parameters and Expression of Estrus

The detection of estrus in confined dairy cows became a greater challenge as milk production increased. Previous studies that took into account only mounting behaviours as a measure of intensity and duration of estrus have consistently recorded a decrease in this behaviour as milk production increased (Rivera et al., 2010). A major question still unanswered is if mounting behaviour can be used as a gold standard for estrous expression (i.e., intensity and duration), considering the challenges faced by dairy cows in free-stall barns and concrete flooring for an activity that leads to significant physical stress on foot and legs. The estrous detection rate in a recent survey (Denis-Robichaud et al., 2016) has been reported to be below 50%, but the proportion of cows truly bred upon estrous detection is still unclear as this data was confounded by timed artificial insemination (AI) use. This extensive failure to submit cows for AI has a major impact in the pregnancy rate of Canadian herds, but also indicates a unique window of opportunity to improve fertility.

A large field study (Lopez-Gatius et al., 2005) described that the two main factors affecting activity increase were lactation number and milk production, whereas the degree of activity increase was positively correlated with fertility after AI. The latter was not clearly stated by the author but was later corroborated by recent studies (Madureira et al., 2015). Milk production, for example, seems to affect the overall sensitivity of pedometers or activity monitors to detect true events of estrous behaviours. However, none of the studies above measured more detailed reproductive physiological events associated with natural estrous behaviours and the level of activity of AAM systems associated with those events. Just recently more robust studies using adequate number of observations of estrus and cows have been published for more reliable conclusions.

Parity

A study by our group identified several risk factors associated with the intensity of estrus expression; multiparous cows expressed lower peak activity and duration of episodes of estrus than did primiparous cows (Madureira et al., 2015). López-Gatius et al. (2005) found that for each additional parity number, walking activity at estrus was reduced by 21%. On the contrary, Walker et al. (1996) described that duration of estrus was nearly 50% shorter for primiparous than for multiparous lactating dairy cows. Our study does not support findings from recent studies that reported no association between parity and physical activity at estrus (Løvendahl and Chagunda 2010; VeerKamp et al., 2000). Methodological differences may explain variation among different studies on the association between parity and physical activity, such as frequency of data transmission from sensors to software, or different breeds of cows. Moreover, the detailed information about different AAM systems reading correlations will be key to properly use automated behaviour data with physiological parameters. In a simple analysis by our group comparing a neck vs. a leg-mounted AAM, correlation between the peak intensity of estrus episodes of both systems was acceptable, but not at a level that justifies a seamless translation of the data from one system to the other

(Madureira et al., 2015; Silper et al., 2015c). Different AAM systems will capture different movements, and different algorithms and software filter the background data in specific manners thereby influencing measurements of baseline levels and relative increases in activity during estrus.

Milk Production

Greater milk production has been negatively correlated with standing to be mounted at estrus. The decrease in concentrations of estradiol, possibly caused by increased hepatic blood flow and steroid clearance, is a possible cause for decreased estrus-related behaviour, most notably the standing to be mounted behaviour. Madureira et al. (2015) also found greater peak intensities and duration in animals with lower milk production, but the difference was most noted in the lowest quartile category. We could assume that the data partially agree with previous research (Rivera et al., 2010), however, it seems that mounting activity is more affected than overall physical activity measured by AAM systems. Recent studies from our group (Madureira et al., 2015; Silper et al., 2015a) found that heifers and cows with lower baseline levels of activity tend to have greater relative activity increase, but not necessarily greater absolute increases in step counts during estrus. In spite of the results discussed above, peak intensity during estrus was still weakly associated with milk production, emphasizing the influence of factors such as body condition score (BCS) and parity, and probably other factors such as group size, health status, and lameness).

There is no clear effect of milk production on conception rates The ability of individual cows to cope with high milk yield and current management practices are important in determining if a negative effect of lactation on overall fertility is more or less likely to occur. It is difficult to establish this relationship because cows with low milk production might be sick from diseases that will also affect the reproductive tract, while high producing cows are often times the healthiest ones.

Body Condition Score

Body condition score was the major factor associated with physical activity at estrus and P/AI (Madureira et al., 2015). This study supported conclusions by Løvendahl and Chagunda (2010), who observed that in the first 5 months after calving, low, early postpartum BCS had a negative correlation with estrous activity. Further support is provided by Aungier et al. (2012), who reported that a 0.25 increase in BCS was significantly correlated with an increase in physical activity prior to ovulation. Cows that lost less than 100 kg of body weight from two weeks pre-calving to five weeks post-calving had greater intensity of estrus in the first two estrus episodes post-partum (Burnett et al., 2015). The specific mechanism by which a temporary state of negative energy balance reduces estrogen-dependent estrus behaviour is unclear.

▪ Detection of Estrus and Relative Intensity

There are plenty of systems available for dairy farmers, but further exploration of the AAM is necessary. Some of these systems have resources such as adaptable thresholds per farm or groups of cows, but these do not seem to be explored or extensively used. For example, adjustments could be made according to season of the year, parity, and BCS. These examples of possible adjustments illustrate the challenge ahead of the dairy industry and the agri-business in general regarding the fast transformation towards heavy use of data management and automation. There is a learning curve on how to use these systems. Even the simplest AAM will probably require some time and patience from herd personnel in order to learn and extract the most from sensors and respective software.

Reproduction Programs and AAM Use in North America

A few studies, normally large surveys, have been able to draw a picture of the state of reproductive programs in North America. Caraviello et al. (2006) showed that over half of all dairy farms in North America used timed AI (TAI) programs, but at the time (mid 2000's) the use of AAM in American farms was likely very small. In Canada, a recent large survey indicated a strong use of TAI programs, but visual detection remains the management system mostly used by farmers (Denis-Robichaud et al., 2016). This number, however, is highly dependent on region. For example, Quebec, which concentrates a large number of tie-stall farms with a small number of cows, tends to use less AAM systems than places like British Columbia where well over half of the herds detect estrus based on AAM.

In this survey, we reported the results from 772 survey answers, which represents 6% of the total number of dairy farms in Canada. The average herd size was 84 lactating cows (median = 60) with herds located in all Canadian provinces. Lactating cows were housed in tie-stall (55%; most in Quebec) and free-stall barns (45%). AAM systems were used in 28% of the participating herds (4% of the tie-stall, but 59% of the free-stall herds) and were consulted for high activity alerts at least twice daily by almost all (92%) users. Interestingly, 21% of the participants never confirmed heat by visual observation before insemination, while 26% always did. Results from this survey highlight the variability in reproduction management among Canadian dairy herds. Knowledge of producers' attitudes toward different management practices should help optimize the development and implementation of reproduction management tools.

Automated Activity Monitors

Current AAM systems are different (e.g., step counts, acceleration of movement, rumination time/frequency, lying time/bouts) regarding their output or variable to be analyzed. Some examples are DELPRO (DeLaval; Sweden), Heatseeker II (Boumatic, USA), CowScout (GEA, Germany), AfiAct II (Afimilk, Israel), CowAlert (IceRobotics, UK) and HR Tag (SCR Engineers, Israel). These AAM are efficient at detecting estrus. Using a neck-mounted device, Valenza et al. (2012) detected 71% of the preovulatory phases but missed 13% of the recorded ovulations. Similarly, with the same sensors, Aungier et al. (2012) reported 72% of the preovulatory follicular phases identified correctly, but 32% of false-positives. In the studies conducted by our group, the positive predictive value for estrus alerts is around 85-90%. It is possible that some of these false positives did not occur because the cut point used to determine high progesterone status (false-positive estrus) was extremely low (progesterone > 0.6 ng/mL). It is agreed that progesterone in milk of 3 ng/mL or higher indicates presence of an active corpus luteum. A study from Denmark (Løvendahl and Chagunda, 2010) using activity tags also showed a 74.6% detection rate and 1.3% daily error rate when using the most efficient algorithm calculated by the authors.

There has been little research on the use of lying and standing behaviour for estrus detection. Rutten et al. (2013) reviewed 48 papers but only two reported lying and standing information. Recently, our group analyzed lying and standing information in relation to the estrous period in more detail (Silper et al., 2015b, 2017). Results from these studies indicate a large potential to improve the accuracy of estrus detection, and the use of quantitative information (e.g., proportional changes on lying behaviours on the day of estrus in relation to the day before and after) from these monitors to assist farm-level decision-making regarding breeding. Brehme et al. (2008) described the absence of lying time over long periods (16 hours) during estrus; however, they did not provide detailed information about measurements or factors that affect lying time. One AAM system (AfiAct II, Afimilk) uses steps, lying time and an index of restlessness in its estrus detection algorithm, but literature regarding its efficiency and measurements of estrus expression is still unclear. Given the variability reported by many and the low levels of estrus expression in general, it seems that combining measurements within one system is potentially a better alternative for reducing false negatives. A combination of activity and lying behaviour data from IceTags (IceRobotics) significantly reduced error rate (false alerts) and increased probability of estrus detection (Jónsson et al., 2011). Peralta et al. (2005) also suggest combinations of systems are the best alternative to enhance detection and conception rates during periods of heat stress. The use of more than one measurement within the same sensor can also enhance specificity and reduce false positives.

▪ Expression of Estrus and Fertility

Effect of Display and Intensity of Estrus in P/AI and Pregnancy Loss

A series of recent studies using different AAM systems, farms, timing of studies and geographical locations reported substantial increases in P/AI from events of estrus of high peak activity (Madureira et al., 2015; Burnett et al., 2018; Madureira et al., 2018) and large decreases in lying time at the day of estrus (Silper et al., 2017). It is a common belief that cows that show 'good' heat are more fertile; however, this tends to be associated with changes in BCS, milk yield, parity and even health status. In fact, we have observed greater peak intensity and duration as BCS increased and in primiparous cows, but greater P/AI still occurred in spite of those and other risk factors known to affect conception rates. Consistently, cows with high peak intensity had approximately 10 to 14 percentage units greater P/AI than cows with low peak intensity, which represents a 35% improvement in fertility (Figure 1; Madureira et al., 2015). Previous to these recent studies only Lopez-Gatius et al. (2005) reported an improvement associated with a relative increase in walking activity. It is possible that information already available in herd management software could be used to calibrate AAM to consider present phenotypical conditions of the cow. The use of peak intensity and duration measurements could assist in the prediction of fertility and improve decision-making in reproductive programs using activity monitors. Moreover, there is potential to use AAM systems as an objective and accurate tool to select animals of superior estrus expression and fertility, although this topic still warrants further research.

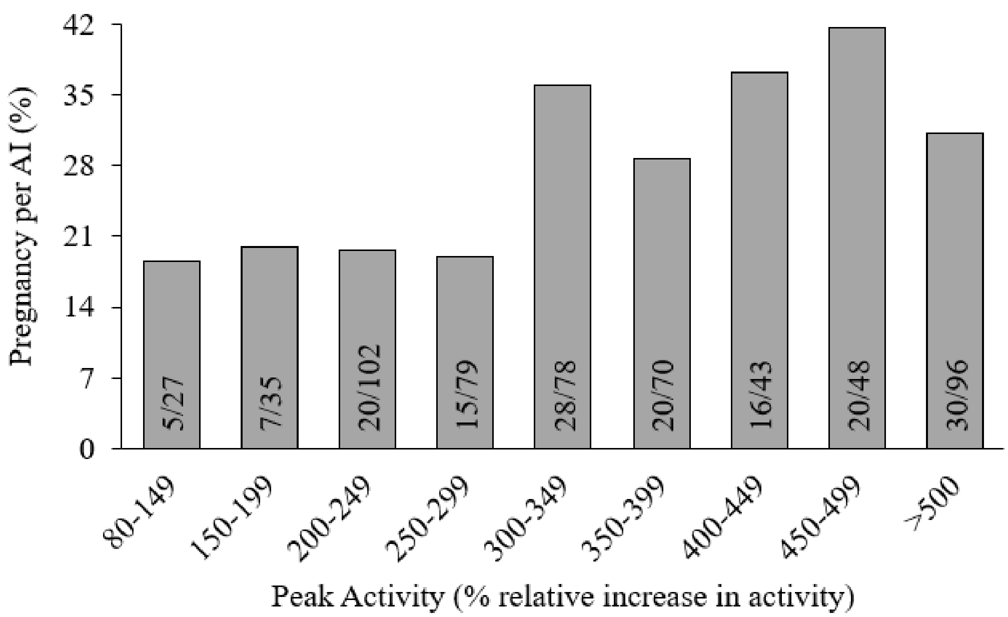

Figure 1. Distribution of pregnancy per AI (%) according to peak activity during estrus detected by a leg-mounted sensor (Madureira et al., 2015).

The display of estrus only (no distinction of intensity) at AI has been associated with a reduction in pregnancy losses. Pereira et al. (2015) performed a large field trial and one of the first studies to describe the immense impact of estrus expression on the reduction of pregnancy losses. Moreover, this study showed that this effect is true for both AI and embryo transfer (ET) based programs, indicating a possible major modification of the uterine environment as the cause for the improved fertility. Furthermore, this group also reported that animals that display estrus at AI had decreased pregnancy losses regardless of the diameter of the pre-ovulatory follicle, which is something we normally observe in our studies regarding intensity of estrus. Most recently, another data set from Brazil (Madureira et al., 2018) also demonstrated the immense effect of estrus intensity on pregnancy loss. Cows with greater intensity of estrus had significant decreases in late embryonic or early fetal losses (Figure 2) demonstrating that the conceptus-endometrium communication in several stages of early pregnancy is compromised. These practical results corroborate our data from beef cows that showed an extensive modulation of gene expression of key transcripts related with the immune system and adhesion molecules (Davoodi et al., 2016). Collectively, it seems that the expression and intensity of estrus have important positive effects on gestation maintenance, particularly by setting an endometrium environment that is more ideal to receive the conceptus.

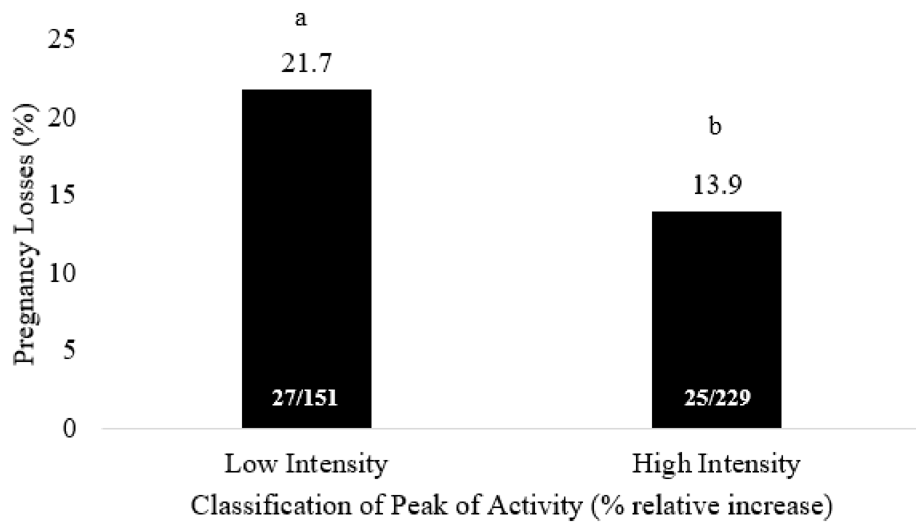

Figure 2. Pregnancy losses (%) according to categories of peak activity during estrus: Low Intensity (< 300 % relative increase) and High Intensity (≥ 300 % relative increase) at estrus episodes detected by the activity monitor (*P* = 0.03; Madureira et al., 2018)

Why Does Absence of Estrus or Low Intensity Estrus Lead to Poor Fertility?

Ovarian Follicles and Estradiol

It was previously mentioned that preovulatory follicle diameter was not different between peak intensity categories, but that does not imply that proestrus or dominance length was similar as there was no control of follicular emergence in recent studies. Therefore, proestrus and dominance length cannot be ruled out as possible causes related to the reduced fertility observed. The correlation between the preovulatory follicle diameter and plasma estradiol tends to be weak (Silper et al., 2015c; r = 0.17) and is in agreement with values reported elsewhere (Sartori et al., 2004; Walker et al., 2008). Although reports have found that a larger follicle is associated with greater concentration of estradiol in plasma (Cerri et al., 2004), it is clear from the most recent experiments that parity, BCS and ultimately milk production are the factors with the greatest impact on circulating concentrations of estradiol. Cows classified as having high activity had similar preovulatory follicle diameter, but slightly greater concentration of estradiol in plasma than cows classified as low activity (Madureira et al., 2015). In spite of the differences in estradiol concentrations found when cows were divided in categories by estrus activity, the peak intensity measured by different AAM systems was only weakly correlated with concentration of estradiol in plasma, demonstrating a greater than expected variation. A recent study by Aungier et al. (2015) observed no correlation between activity clusters measured by AAM and FSH, LH and estradiol profiles. However, a greater peak concentration of estradiol in plasma was associated with standing and estrus-related behaviours. The ovulation of pre-ovulatory follicles with similar diameter between high and low estrous intensities would suggest little change in concentrations of progesterone after AI, but results shown later in this manuscript suggests that concentrations of progesterone at- and post-AI are more likely causes of the P/AI and pregnancy loss observations.

Ovulation Rate and Timing

Another possible factor influencing P/AI is the ovulation profile from cows with different peak intensity at estrus. Burnett et al. (2018), using lactating cows found a larger variation in ovulation times and a greater prevalence of cows ovulating before the expected ideal time after the beginning of estrus. While this observation is certainly important to explain our observations, it is limited to cows expressing very low peak intensity during estrus, because the threshold dividing high and low peak intensity categories was over

300%. It is important to note that one of the mentioned studies used estradiol cypionate to induce estrus and ovulation, therefore bringing circulating estradiol to high concentrations. In spite of this, the peak intensity measured by a pedometer system still significantly affected P/AI results (Madureira et al., 2018).

Madureira et al. (2018) and Burnett et al. (2018) observed, using different AAM systems, a greater failure of ovulation rate of cows that displayed low intensity estrus vs. those that displayed high intensity estrus. In general, of all the estrus episodes detected by different AAM, about 5-7% fail to ovulate. However, nearly all of that failure is associated with cows expressing low intensity estrus.

Progesterone

A study by Bisinotto et al. (2015) aimed to modify concentrations of progesterone during the growth of the preovulatory follicle comparing the first with the second follicular wave. The results show how exogenous progesterone (2 intravaginal devices) is able to 'rescue' a preovulatory follicle of the first follicular wave to yield optimal fertility. An interesting finding from this study related to estrus is that animals that ovulated follicles from the first follicular wave growing under low concentrations of progesterone in plasma (worst possible scenario in this study), but that expressed estrus at AI, had P/AI similar to the best treatments. A study just completed by our group (Madureira et al., 2021), aimed to determine the impact of estrus expression, detected by an AAM, on progesterone concentrations at and post-AI. Animals had their ovaries scanned by ultrasound at each collection for confirmation of ovarian structures. Animals with low activity had higher concentration of progesterone and lower concentrations of estradiol upon detection compared with animals with high activity. Follicle diameter did not differ between animals with high or low peak of activity ($P = 0.41$), but much higher concentrations of progesterone on days 7, 14 and 21 post-AI were found in animals with greater estrus expression. Size of the corpus luteum on days 7, 14 and 21d post-AI did not differ between animals that expressed high or low activity. In conclusion, animals that had higher expression of estrus had greater P/AI and a progesterone profile at- and post-AI normally associated with improved early embryonic development.

Endometrium Environment

Several studies have shown the dominant effect of pre- and post-exposure of progesterone relative to AI, proestrus length or estradiol levels on reproductive tissues, particularly the endometrium and the conceptus at various stages of early development. Studies that modified follicular dominance length (Cerri et al., 2009), concentrations of progesterone during diestrus (Cerri et al., 2011), proestrus length and estradiol exposure (Mussard et al., 2003; Bridges et al., 2005), production parameters (e.g., lactation and age; Sartori et al., 2002) and most recently health (Ribeiro et al., 2016) have described these effects on fertilization, embryo quality and uterine environment. However, in spite of marked effects related with the aforementioned modifications of the estrous cycle, not much emphasis has been placed on the isolated or additive effect of expression of estrus on reproductive tissues. In order to answer some of these questions, we aimed to investigate the association of estrus expression at the time of AI with the expression of critical genes in the endometrium, corpus luteum and embryo during the pre-implantation period, more specifically on day 19 of gestation (Davoodi et al., 2016). In addition, the difference in estrus expression was evaluated for reproductive parameters such as corpus luteum volume, conceptus size, concentration of progesterone in plasma, and follicle diameter. Evidence from this study supports our hypothesis that estrous expression positively influences the expression of target genes important for embryo survivability. Cows that expressed estrus behaviour near AI had a significant improvement in the profile of endometrium gene expression critical for suppressing the local maternal immune system and likely improving adhesion between endometrium epithelial cells and conceptus, as well as partly inhibiting the mRNA machinery for PG synthesis. Genes related to the immune system and adhesion group in the endometrium were also significantly affected by concentration of progesterone in plasma on day seven. Results from the gene analysis of the corpus luteum also confirmed down-regulation of cellular pathways associated with apoptosis (programmed cell death) and prostaglandin synthesis which favours corpus luteum maintenance and secretion of progesterone, both key to sustain pregnancy (Davoodi et al., 2016). Moreover, cows that displayed estrus yielded longer conceptuses, which can be associated with better chances of survival. The effects of expression of estrus seems to interact with progesterone concentration on day seven of the estrous cycle in a way that positively influences endometrium receptivity and embryo development. The specific causes that lead to the presence or absence of estrus expression are unknown based on the data collected in this study (Davoodi et al., 2016) and warrant further investigations. The expression of estrus can indicate the state of sensitivity of the hypothalamus to estradiol and perhaps the best timing for the optimal function of all other reproductive tissues related with the survivability of the early embryo.

Reproduction Programs

Reproductive programs with intensive use of TAI protocols are still the ‘go to’ method to improve pregnancy rates. Recent field trials compared different combinations of TAI and AI upon estrus detection using AAM. Conception risk (30% vs. 31%) and days to pregnancy (137 and 122) were not different among cows bred by TAI or following estrus detection by an AAM system (Neves et al., 2012). Other studies have experimented with different combinations of use between AAM and TAI programs. Overall results indicated that it is possible to achieve similar pregnancy rates in more estrus detection-intensive programs. Collectively, these large field trials aimed to modify several factors that are key to the response of the dairy’s reproduction program, particularly in the first AI. For instance, the voluntary waiting period varied from 50 to 100 days in milk depending on the treatment. The use of pre-synchronization protocols that could either focus on induced estrus (progesterone-based) or cyclicity and ovulation synchrony (GnRH based) were tested. All the studies demonstrated that the combination of methods (TAI and AAM) is perhaps the best reproduction program as it maintains high rates of conception while submitting a large number of animals to AI, while minimizing to a certain extent the use of pharmacological assistance. Timed AI protocols are still necessary as a safeguard for a proportion of animals that would not be bred upon estrus up to 100 days in milk. The question of when to intervene with TAI protocols is probably an area that could still gain valuable information from future research. The work performed in Ontario (Denis-Robichaud et al., 2018) is probably the most extreme when comparing a TAI only based program vs. one that allows long periods for spontaneous estrus detection after the end of the voluntary waiting period. In summary, there will be several factors that will influence the final result of the reproductive program on specific farms, but the literature now suggests that AAM can be incorporated into it without loss of efficiency. A recent study performed in British Columbia (Burnett et al., 2022) tested whether it was possible to use the information from the activity monitor to modify a breeding decision at the farm level. Animals were divided into four groups based on the intensity of estrus expression and on GnRH treatment at the time of AI. High estrus expression with no GnRH injection (HighNG), low estrus expression with no GnRH injections (LowNG), high estrus expression with a GnRH injection (HighG) and low estrus expression with a GnRH injection (LowG). The hypothesis was that, based on the previous results showing unfavourable ovulation failure rate and timing in cows expressing low intensity estrus, the LowG group would significantly improve P/AI. The study has not been completed but the results so far are positive. The LowG group not only improved P/AI but did so up to levels found in the high intensity estrus groups (Figure 3).

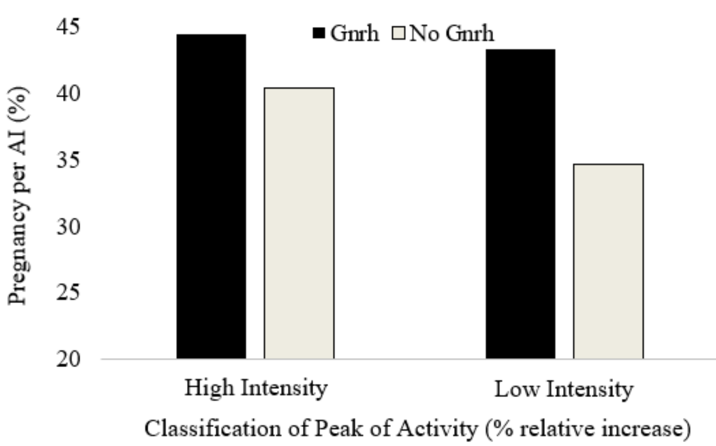

Figure 3. Pregnancy per AI (%) according to categories of peak activity during estrus: Low Intensity vs High Intensity (threshold of approximately 250% relative increase) (Burnett et al., 2022).

Lastly, our group tested the effect of estrus intensity on success of embryo transfer (ET) and collection (Madureira et al., 2022). In the first experiment, Holstein heifers (10.5 to 14.5 months) were superovulated (n = 69 from 51 animals) for the collection of embryos and on the day of estrus, the total number of follicles were counted. Then, embryos were collected, counted, and assessed for viability. In the second experiment, Holstein cows were synchronized and seven days post-estrus were implanted with an embryo (n=1,147 from 657 cows). Overall, cows with higher peak activity had a higher number of total embryos collected (10.2 ± 1.2 vs. 6.0 ± 1.3 embryos; $P = 0.01$) and a higher percent of those embryos were viable (53.1 ± 5.0 vs. 23.4 ± 5.1%; $P < 0.001$). In the second experiment, 89.1% of cows expressed estrus prior to ET. Animals expressing estrus prior to ET had substantially higher P/ET than those that did not (35.8 ± 1.6 vs. 5.9 ± 4.9%; $P < 0.001$). Of the animals that expressed estrus, cows with higher estrus expression had higher ET success than those with low estrus expression (41.5 ± 2.3 vs. 30.6 ± 2.2%; $P < 0.001$). In conclusion, estrus expression is important for both periods before and after ET as seen by more viable embryos and higher P/ET for animals with greater estrus expression.

It is very likely that the adoption of AAM systems as part of large reproduction programs will vary largely from farm to farm. Work from Neves et al. (2012), Burnett et al. (2017) and Denis-Robichaud et al., (2018) demonstrated a large variation by farm in the adoption of TAI and AI upon AAM alerts within the same treatment. Another advantage of the combination of the TAI and AAM is probably the reduction in the use of pharmacological interventions. However, it is yet to be demonstrated how these programs would behave under sites exposed to intense heat stress such as Brazil, as temperature tends to have a major impact on the detection of estrus and intensity.

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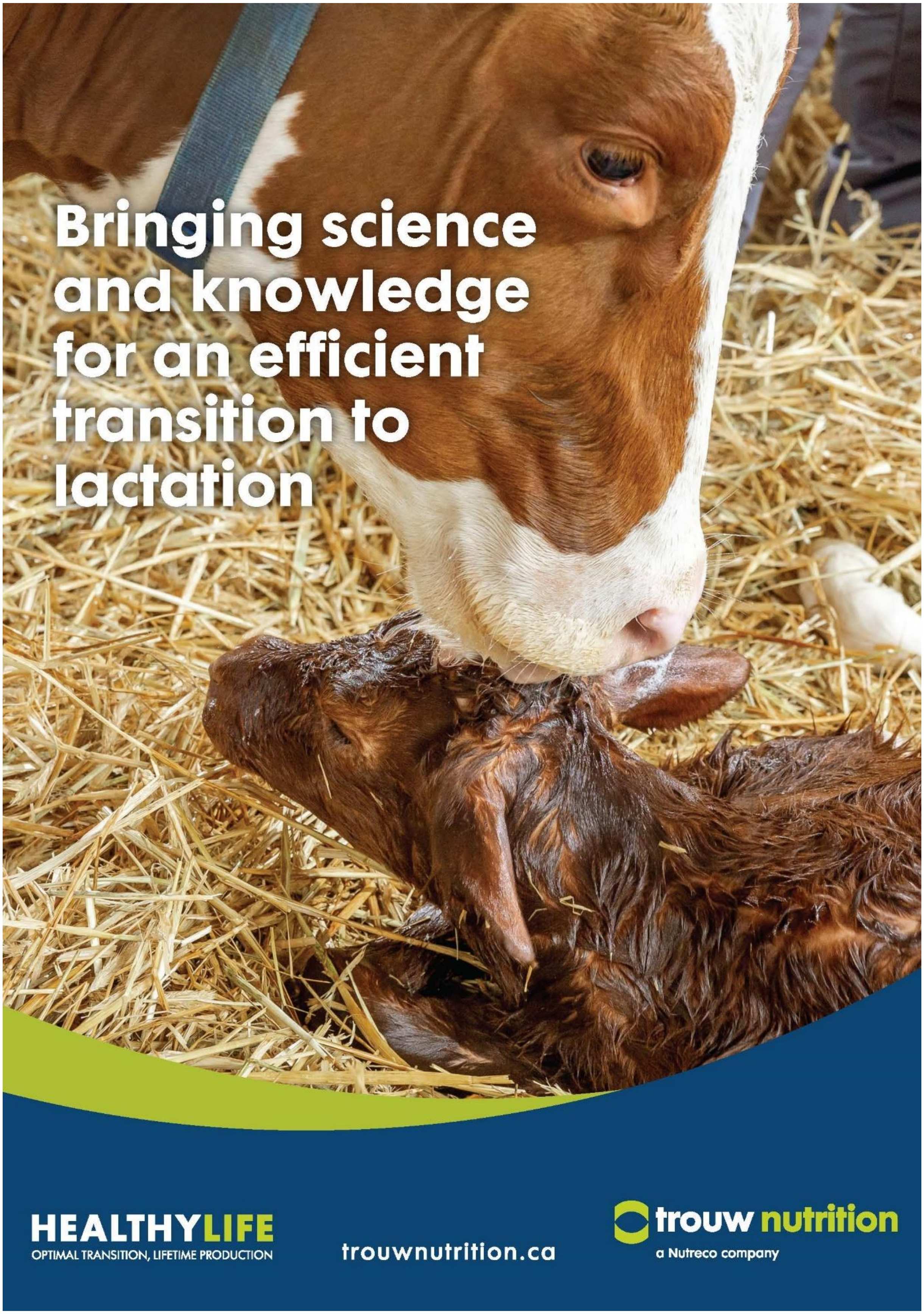
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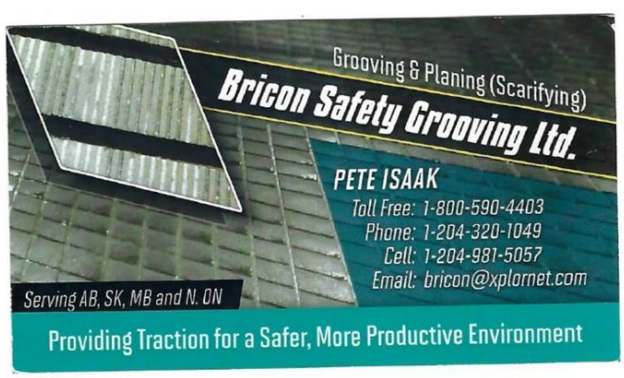
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Increasing fitness for transport in cull dairy cows

N. Berdusco[1], D. F. Kelton[1], K. M. Wood[2], D. B. Haley[1], and T. F. Duffield[1]
[1]Dept. of Population Medicine, University of Guelph, 50 Stone Rd E, Guelph, ON, N1G 2W1; [2]Dept. of Animal Biosciences, University of Guelph, 50 Stone Rd E, Guelph, ON, N1G 2W1· berduscn@uoguelph.ca

Welfare of cull cows during transport to slaughter is a current concern in the Canadian dairy industry. Cull cows sold through auction often have a high prevalence of lameness, low body condition score (BCS), hock lesions, and udder engorgement. Transport may further exacerbate these conditions. To address these challenges, thirty-seven cows were selected and randomly assigned to the experimental or control group. Experimental cows (Fed; n=18) were dried off, fed for 60 days, then sent to slaughter, whereas control cows (Direct; n=19) were sent direct to slaughter. Fed cows were assessed for locomotion (5-point scale), BCS (5-point scale), hock lesions (3-point scale), and udder engorgement (3-point scale) weekly until one day before slaughter. Weights of the Fed cows were determined at time of enrollment in the trial and measured again the day before slaughter. Simple t-test and chi-square statistics were used to compare experimental groups for continuous and dichotomous outcomes, respectively. Fed cows gained an average of 135.6 kilograms over the 60 days (SD $\pm$ 75.88). Direct cows had an average weight at slaughter of 754.6 kg, whereas the Fed cows' average weight was 839.8 kg (P<0.05, SD $\pm$ 93.94). The fed cows' average BCS at the start of the trial was 2.4, and at slaughter was 3.5, with an average gain of 1.2 BCS points. At slaughter, proportion of udders involuted in the Fed group was 44.4% (n=8) and in the Direct cows, was 0% (P<0.05, SD $\pm$0.50). There were no significant differences in locomotion or hock lesions between the fed and direct to slaughter groups (P>0.05).
Take home message: Due to the improved BCS and udder scores, cows fed for 60 days may be better prepared for transportation to slaughter, as well as earn producers more money in the auction ring due to increased weight and body condition.

The effect of dietary cation-anion difference and dietary buffer for lactating dairy cattle during mild heat stress

C.A. Bertens[1], C. Stoffel[2], M. Crombie[2], and G.B. Penner[1]
[1]University of Saskatchewan, Saskatoon, SK S7N 5A8; [2]Papillon Agricultural Company and MIN-AD Inc., Easton, MD 21601.
claire.bertens@usask.ca

The objective was to investigate the interactive effect of dietary cation-anion difference (**DCAD**) and dietary buffer supply on dry matter intake, ruminal fermentation, milk and milk component yield, and gastrointestinal tract permeability in lactating dairy cattle exposed to mild heat stress. Sixteen lactating Holstein cows including 8 cannulated primiparous (80 ± 19.2 DIM) and 8 non-cannulated multiparous (136 ± 38.8 DIM) cows, were housed in a tie-stall barn with a temperature-humidity index (THI) between 68 and 72 from 0600 h to 1600 h followed by night cooling. The experimental design was a replicated 4×4 Latin square (21-d periods) with a 2×2 factorial treatment arrangement. Diets contained low or high DCAD (**LD** = 17.6, **HD** = 39.6 mEq/100g DM) using NH_4Cl and Na-acetate with low or high buffer (**LB** = 0%, **HB** = 1% $CaMg(CO_3)_2$). Total and post-ruminal gastrointestinal tract permeability were evaluated using Cr-EDTA and Co-EDTA, respectively. Treatments had no effect on DMI, milk yield, protein yield, or mean ruminal pH. However, HD increased milk fat by 0.14% and milk fat yield by 40 g/d whereas HB reduced milk fat percentage by 0.12% with no effect on milk fat yield. Buffer supplementation reduced urinary excretion of Co by 26.8% and tended to reduce urinary Cr excretion by 10.2%. Across all treatments 70.8% of the Cr recovery was represented by Co indicating greater post-ruminal permeability. Feeding HD improved blood acid-base balance and increased urine volume by 4 kg/d. While there was no interactive effect between DCAD and buffer, DCAD increased milk fat yield and $CaMg(CO_3)_2$ modulated intestinal integrity in lactating dairy cattle exposed to mild heat stress.
Take home message: When lactating dairy cows in western Canada experience mild heat stress, elevating DCAD from 18 to 40 mEq/100g DM has potential to increase milk fat yield and dietary $CaMg(CO_3)_2$ supplementation may improve intestinal barrier function despite the absence of ruminal acidosis.

Effects of offering free choice timothy hay in addition to TMR during the first five days postpartum on health and performance of dairy cows

L. E. Engelking and M. Oba
University of Alberta, engelking@ualberta.ca

Fresh cows often experience inflammation and low dry matter intake (DMI) which subsequently reduce milk yield. Some producers offer free choice hay, alongside total mixed ration (TMR), to fresh cows which is intended to promote DMI and rumination, and reduce inflammation, each of which may contribute to greater milk yield, but its effects have not been assessed through research. Thus, our objective was to assess the effects of offering free choice hay to fresh cows on milk yield, DMI, rumination, plasma metabolites, and serum inflammatory markers. Thirty-two multiparous cows were assigned to receive no hay (n = 12) or free choice timothy hay (61.6% NDF; 9.6% CP; n = 20), in addition to TMR, for the first 5 d postpartum. Both treatment groups were fed the same postpartum TMR containing 48% barley silage and 52% concentrate, and 26.8% starch, 33.0% NDF, and 23.4% forage NDF. Daily hay intake ranged from 0 to 4.7 kg/d (DM basis) or 0 to 55.2% (as a % of total DMI) for cows offered hay. Among them, cows who consumed more hay (as a % of total daily DMI) for the first 5 d postpartum had greater plasma ketone concentration (P = 0.01; r = 0.60), and greater serum concentration of haptoglobin, an inflammatory marker ($P < 0.01$; r = 0.68), within 24 h of calving. These results suggest that cows experiencing ketosis or inflammation postpartum may be motivated to consume more hay. On d 3 after calving, cows offered hay tended to have a lower serum concentration of haptoglobin compared to cows not offered hay (0.95 vs. 1.52 mg/mL; P = 0.08). However, cows offered hay had lower TMR DMI (15.0 vs. 17.1 kg/d; $P < 0.01$), and total DMI (TMR + hay intake; 15.9 vs. 17.1 kg/d; P = 0.05) for the first 5 d postpartum although rumination time, plasma energy metabolite concentrations, and milk yield were not different between treatments at any time points.
Take home message: Offering free choice hay to fresh cows may mitigate postpartum inflammation but may not increase milk yield due to reduced DMI.

Effects of supplementing colostrum beyond the first day of life on growth and health factors in preweaned Holstein heifers

H. McCarthy[1](hmccar01@uoguelph.ca), M. Cantor[1], A. Lopez[1], A. Pineada[1], D. Renaud[1], M. Nagorske[2], and M. Steele[1].
[1]University of Guelph, [2]Saskatoon Colostrum Company Ltd

The preweaning period of calves is defined by high morbidity and mortality rates, leading to financial losses. Research regarding ways to improve the health of calves continues to be crucial to the success of the dairy industry. The objective of this study was to explore the effects of supplementing colostrum replacer (CR) beyond the first day of life to calves on health and growth performance. Holstein calves (n=200; 50/TRT) were enrolled at birth, fed CR at 0 and 12h, and assigned to 1 of 4 treatments: 100% milk replacer (MR) from d2-49 (**CON**); 50%CR50%MR d2-3, and 100%MR d4-49 (transition; **TRAN**); 10%CR100%MR d2-14 and 100%MR d15-49 (extended; **EXT**); or 50%CR50%MR d2-3, 10%CR100%MR d4-14, and 100%MR d15-49 (**TRAN+EXT**). Body weight was recorded at birth and weekly until week 7, and blood serum samples were taken daily (d0-7) and weekly until week 7. In addition, a health assessment was completed daily. All data were analyzed using PROC GLIMMIX and LIFETEST in SAS (version 9.4; SAS Institute Inc., Cary, NC). Calves fed TRAN, EXT, and TRAN+EXT had greater average daily gain (ADG) in the first 4 weeks of life (P = 0.02) compared to CON calves. The incidence and length of diarrhea and respiratory illness did not differ by treatment; however, the TRAN, EXT, and TRAN+EXT calves had a delay in onset of diarrhea (P = 0.03). Calves fed TRAN and EXT were at a lower hazard of mortality (P = 0.05) compared to CON calves. Serum IgG levels did not differ by treatment (P = 0.80). Supplementing CR to dairy calves for a minimum of 3d postnatal positively impacts ADG, delays the age of diarrhea onset, and reduces the hazard of mortality during the preweaning phase. Future research should look to further refine the supplementation strategy of CR and explore the mechanism of action.
Take home message: Supplementing colostrum beyond day one of life can be an effective strategy to improve growth, delay diarrhea onset, and reduce mortality in preweaning dairy calves.

Exploring persistence of non-aureus staphylococci in the mammary gland using a lactating cow model

Dennis Vu, Jeroen De Buck.
Faculty of Veterinary Medicine, University of Calgary, Devu@ucalgary.ca

Overuse of antibiotics has resulted in the emergence of antibiotic-resistant bacteria, and thus, alternative treatments are required. A promising alternative is the use of bacteriocins – antimicrobial proteins produced by bacteria that can inhibit *S. aureus*. Our hypothesis is that by creating a non-aureus staphylococcus (NAS) probiotic through genetically engineering a bacteriocin gene cluster into its genome, it will be able to inhibit *S. aureus* and prevent mastitis. To achieve this, we needed to find a persistent and non-inflammatory NAS strain that can colonize cow mammary glands by using an experimental mammary infusion model. Future objectives include the genetic modification and characterization of the persist NAS strain to produce bacteriocins. We Infused 4 different mixtures of NAS containing a total of 16 different NAS isolates into 3 lactating cows' mammary glands. The milk samples were tested daily to see which strains remained. At the end of the two-week trial, the cows were euthanized, and tissue analysis was performed to see where different NAS colonized. From the 4 different mixtures, the three most persistent NAS isolates were *S. devriesei* 1316, *S. pasteuri* 2657, and *S. warneri* 2993. These three persistent NAS were then infused individually into 3 lactating cow mammary glands to see their persistence and individual effect on somatic cell count (SCC). Euthanasia and tissue analysis was performed in a similar manner to above afterwards. *S. warneri* 2993 was the most persistent strain as it was isolated from milk 28 out of 42 times while the other two isolates grew less than 4 out of 42 times. *S. warneri* 2993 did increase the SCC past the subclinical mastitis threshold at days 2 to 5. However, for the rest of the days, the SCC was stayed below the subclinical mastitis threshold. To conclude, *S. warneri 2993* was the most persistent strain with the lowest effect on SCC and will be used to introduce protective bacteriocin genes into.
Take home message: This was the first lactating cow infection trial done at the University of Calgary showing a intramammary NAS infusion can result in colonization of bovine mammary glands. *S. warneri* 2993 was the most persistent strain with the lowest effect on SCC. This strain will now be modified to be a probiotic producing bacteriocins to prevent mastitis.

Importance of selective antibiotic use: Drying off and clinical mastitis treatments

Herman W. Barkema[1*]

[1]Faculty of Veterinary Medicine, University of Calgary, 3330 Hospital Drive NW Calgary, AB, T2N 4N1. Email: barkema@ucalgary.ca

Take Home Messages

- The majority of antimicrobial use on dairy farms is for mastitis treatment or dry cow therapy.
- Changing from blanket to selective dry cow therapy can decrease on-farm antimicrobial use without negative effects on udder health or milk production.
- Teat sealants prevent new dry period intramammary infections and must be part of a selective dry cow therapy protocol.
- Using a selective clinical mastitis protocol based on rapid diagnostic tests will not negatively affect cure rates, somatic cell counts, or recurrence of clinical mastitis.

Introduction

Antimicrobial Use and Resistance

Antimicrobial use (AMU) increases emergence of antimicrobial resistance (AMR). Although evidence regarding the scope of the contribution of AMU on dairy farms towards AMR in human health care settings is lacking, the World Health Organization and other international agencies are pressuring livestock industries to reduce AMU. Fortunately, reducing AMU in livestock can decrease prevalence of AMR in livestock and humans. Furthermore, effects of reducing AMU in livestock on AMR in human pathogens potentially acquired from livestock are more prominent in people with direct contact with animals compared with the general public. Therefore, AMR in livestock is particularly important for farmers and their families, and for farm workers.

The majority of AMU on dairy farms is for mastitis treatment and prevention, with dry cow therapy (DCT) using high concentrations of long-acting antimicrobials. Due to pressure to reduce overall AMU in food animals and eliminate preventive antimicrobial treatments, selective DCT (SDCT; treatment of selected cows at drying off) is being considered instead of blanket DCT (BDCT; treatment of all cows at drying off), and selective treatment of clinical mastitis (CM) instead of treating all cases of CM. By reducing livestock-associated AMU there is potential to reduce prevalence of AMR, with expected benefits for both animal and public health. In addition to reducing overall AMU, the dairy industry signals it is making more prudent use of antimicrobials and promoting sustainability.

*The following people co-authored this conference paper: Kayley D. McCubbin[1], Ellen de Jong[1], Julia Bodaneze[1], Ben Caddey[1], Jennifer A. Ida[1,3], Karin Orsel[1], Diego B. Nobrega[2], Guillaume Lhermie[1], Jeroen De Buck[1], David F. Kelton[2], and John P. Kastelic[1].

[1]Faculty of Veterinary Medicine, University of Calgary, 3330 Hospital Drive NW Calgary, AB, T2N 4N1; [2]Dept. of Population Medicine, Ontario Veterinary College, University of Guelph, 50 Stone Road E., Guelph, ON, N1G 2W1; [3]College of Veterinary Medicine, Cornell University, Ithaca, NY 14850, USA

Dry Cow Therapy

Blanket DCT is a key component of the National Mastitis Council (NMC) Mastitis 10-point Control Program and the previous 5-point mastitis control plan to prevent and treat contagious udder infections. Consequently, it is done in many countries. In contrast, SDCT involves selecting only cows or mammary quarters with existing udder infections or at increased risk of developing new infections to be given antimicrobials at drying off.

Although SDCT has been done in Scandinavia for decades, it has only recently been considered in national policies in many other countries. This is possible due to changes in mastitis epidemiology, including considerable decreases in percentage of cows with an udder infection at drying off, lower prevalence of contagious mastitis bacteria such as *Streptococcus agalactia*e and *Staphylococcus aureus*, and reductions in bulk milk somatic cell count (SCC). In addition, there are now reliable and affordable diagnostics and teat sealants (TS). With these improvements, there is an opportunity, or arguably an obligation, to reduce or perhaps eliminate preventive AMU in the dry period.

Treatment of Clinical Mastitis

As non-selective or blanket antimicrobial treatment of CM is common worldwide, interventions such as selective antimicrobial treatment of CM are an opportunity to refine AMU. The main principle of selective antimicrobial treatment of CM is to only treat Gram-positive (most frequently *Staphylococcus* and *Streptococcus*) cases that will respond to antimicrobials. Not treating all CM cases with antimicrobials is possible due to improvements in udder health management practices and diagnostics. In many countries, a large percentage of CM cases are caused by Gram-negative bacteria (most frequently *Escherichia coli* and *Klebsiella*). There are now on-farm diagnostic tests to identify the bacteria or group of bacteria (Gram-positive and Gram-negative), or to determine that no bacteria are present.

Aims and Objectives

In this review, we will first summarize core principles and elements of SDCT and selective treatment of CM protocols. In addition, a summary of positive and negative consequences associated with SDCT and CM treatment protocols will be presented. Finally, we discuss challenges in promoting antimicrobial stewardship strategies and highlight future steps.

▪ Principles of Selective DCT and Treatment of CM

Dry cow therapy

Herd selection

There are general indications, but no definitive guidelines, to make herd-level selections for farms to adopt SDCT. Herd and udder health characteristics are important to consider and should be optimized before SDCT implementation. Herd considerations can include bulk milk SCC (BMSCC) thresholds (e.g., < 250,000 cells/mL), CM incidence, and factors that influence these, e.g., hygienic drying off practices and mastitis bacteria profiles. Major pathogen udder infections at drying off and incidence of new major pathogen udder infections in the dry period must be minimized. Additional considerations include good record keeping (i.e., CM cases, antimicrobial treatments, etc.), to know whether cows had CM during lactation or had other health consequences (i.e., CM recurrence, culling, etc.), and to determine if a SDCT protocol was successful.

Cow selection

The main challenge to implementing SDCT is deciding which cows or quarters should be treated with antimicrobials. The objective is to accurately identify cattle likely to have a major pathogen udder infection and likely to benefit from antimicrobial treatment. If antimicrobials are applied preventively, cows or quarters at high risk of acquiring a new major pathogen udder infection during the dry period need to be identified. Identification of udder infections can be done with various methods: SCC at cow- or quarter-levels, identification of bacteria, California Mastitis Test (CMT), milk leukocyte differential, conductivity testing, lactate dehydrogenase, or N-acetyl-β-D-glucosaminidase. Further, Lactanet can identify cows that are good candidates to be dried off without DCT. Figure 1 provides a suggested protocol.

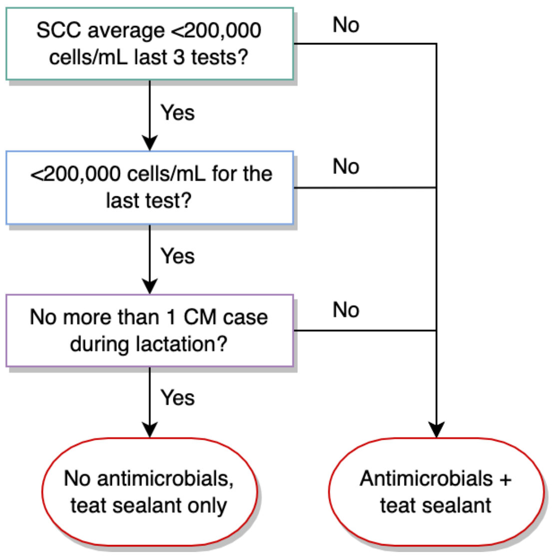

Figure 1: Example of a selective dry cow therapy protocol.

Teat sealants

To prevent new udder infections in the dry period, it is important to reduce the likelihood that bacteria enter the teat canal and proliferate in the udder. Up to 50% of teats remain open ten days after drying off, and 23% are open for six weeks. Teat sealants were developed to reduce new udder infections by creating a physical barrier with more reliability than keratin plug formation. Although TS help to reduce preventive AMU, they do not replace other measures to prevent udder infections in the dry period such as bedding hygiene.

There are external and internal TS. External TS are external coatings on the teat end, usually applied with a dipping cup. However, they can be difficult to apply correctly, are ineffective long-term, and require frequent reapplication. Internal TS is an inert product infused into the teat canal, ideally forming a physical barrier that remains in the distal teat cistern throughout the dry period but stripped out the first milking after calving. An internal TS plug will still be present at first milking in 83% of treated quarters. The National Mastitis Council currently recommends TS application as part of DCT. Teat sealant material must be removed from the udder before milk is put into the bulk tank.

Internal TS use without concurrent AMU in cows identified as not infected at drying off has been successful, with no difference compared with BDCT for CM incidence in the dry period and during the first 120 days in milk, dry period new infection risk and at calving, SCC, and milk production in the subsequent lactation. Internal TS reduced new udder infections in the dry period by 52% compared with no treatment and by 23% compared with antimicrobials in the udder in cows entering the dry period without an infection.

In a meta-analysis (1974-2020), if internal TS was administered to untreated, healthy quarters or cows at drying off, there was no difference between BDCT and SDCT for the risk of new udder infections during the dry period and at calving, and early lactation CM risk, milk yield, and SCC (Kabera et al., 2021). However, without an internal TS, the risk of new udder infections in the dry period and harboring an udder infection at calving was higher with SDCT than with BDCT (Kabera et al., 2021), emphasizing the importance of TS.

Clinical Mastitis

Decisions regarding antimicrobial administration for CM aim to achieve bacteriological cure and clinical cure, and to avoid negative health and economic consequences. The objective of selective treatment of CM is to reduce and refine AMU by treating only CM cases with the highest odds of clinical cure, and to withhold antimicrobial treatment from CM cases unlikely to benefit. This can be achieved by considering signs associated with the current CM case, (potential) causal bacteria, and cow-related factors such as SCC and CM history (Figure 2). Combining these factors can be used to identify CM cases less likely to benefit from antimicrobial treatment. Other cow factors such as parity and lactation stage also impact clinical cure but are not important for choosing antimicrobial administration for CM cases. Antimicrobial susceptibility is important, but usually not available in time and will not influence the decision to treat.

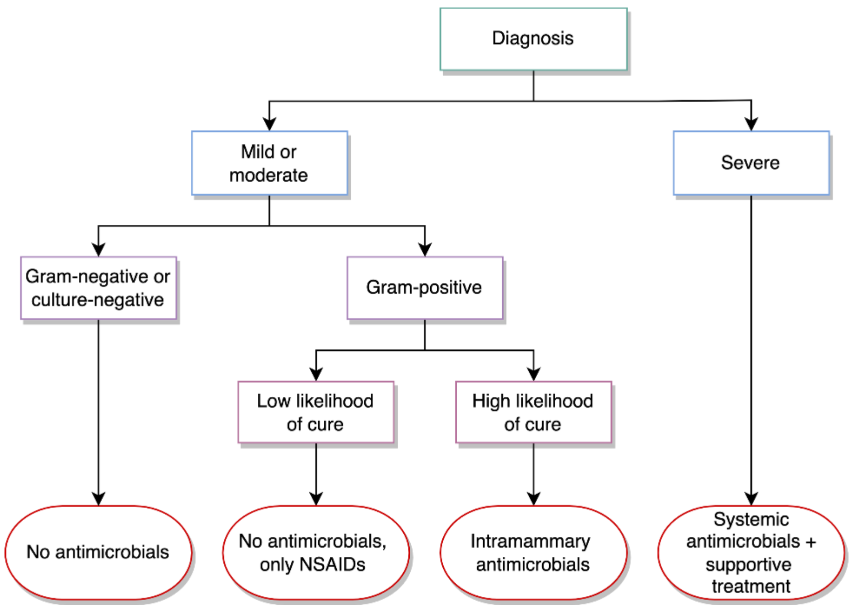

Figure 2: Selective clinical mastitis treatment protocol.

Severity

Severity of CM is generally classified as mild (changes in milk only), moderate (infected quarter has signs of inflammation), or severe (including signs of general illness). Typically, mild and moderate CM cases are treated only with intramammary antimicrobials. For those cases, bacteriological and clinical cure rates are not affected when treatment in the udder is delayed for a maximum of 24 hours after onset compared to immediate initiation, allowing time to get diagnostic test results.

With automated milking systems, systemic (in muscle, intravenous or under the skin) AMU may be more practical. Systemic antimicrobials for mild and moderate CM, in addition to intramammary AMU or alone, is common in Scandinavia, Estonia, and Spain. There is little evidence that systemic antimicrobials are better than treatments in the udder. Severe CM cases typically receive systemic antimicrobials in addition to supportive treatments (i.e., anti-inflammatories and fluid therapy), although there is limited evidence that systemic antimicrobials are necessary.

Identifying causal agent

Because CM typically occurs after an inflammatory response to an udder infection, many CM cases are detected after successful bacteriological clearance. If viable bacteria are no longer present in the udder, and bacteriological culture of a milk sample is negative, antimicrobial treatment should not be considered. Additionally, when a mild or moderate case is caused by an infection with *Escherichia coli* (Gram-negative), antimicrobial treatment is not indicated because there is a high spontaneous cure rate that is not improved by antimicrobials. However, when the Gram-negative agent is *Klebsiella*, antimicrobial treatment increases bacteriological cure rates. In addition, udder infections caused by non-bacterial pathogens such as yeast and algae do not respond to antimicrobials and should not be treated with them. These non-bacterial pathogens also produce negative bacteriological cultures. Various on-farm testing methods are available to identify the cause of CM and can be used on-farm or in a laboratory. Getting results within 24 hours is key for timely treatment of Gram-positive CM cases.

Expected chance of cure

In combination with bacterial identification, cow-level SCC and CM history can be used to identify CM cases with a high probability of cure and should be combined with rapid diagnostic tests to decide whether antimicrobial treatment is appropriate. Cattle with a persistent high SCC (i.e., chronic subclinical mastitis; typically defined as composite SCC > 200,000 cells/mL on at least two of three consecutive SCC records) have a lower likelihood of cure. Similarly, cases preceded by CM in the same lactation also have a lower likelihood of cure. For both situations, nonsteroidal anti-inflammatory drugs (NSAID) only (and no antimicrobial treatments) are favored.

Other considerations: anti-inflammatory treatment

Regardless of antimicrobial treatment, giving an NSAID to reduce pain and inflammation is recommended for all severe CM cases. Providing NSAID to mild and moderate cases in addition to antimicrobials lowers SCC and reduces the risk of culling compared to providing only antimicrobials (if most cases are caused by Gram-positive bacteria, e.g., *Streptococcus uberis* or *Staphylococcus aureus*). Therefore, NSAID are strongly indicated for severe CM cases, and also benefit mild and moderate cases. However, milk withdrawals for NSAID products may reduce farm profits. Thus, consideration of NSAID for mild and moderate CM cases should be discussed with the herd veterinarian.

Other types of supportive treatments (i.e., fluids, frequent milk-out, oxytocin, calcium, hypertonic saline, and corticosteroids) are sometimes considered for CM treatment, although limited research is available regarding their effects on clinical signs and clinical cure.

▪ Impact of selective treatment practices

Dry cow therapy

Udder Health

If SDCT programs are successful, udder infection dynamics (i.e., new udder infections, bacteriological cures) during the dry period will be similar to BDCT, resulting in a similar percentage of udders infected at calving. If this is achieved, udder health and performance in the subsequent lactation should be equivalent to BDCT. The majority of recent clinical trials concluded SDCT can be implemented in commercial dairy herds without negative consequences for udder health. Similarly, recent meta-analyses concluded udder health was similar for BDCT and SDCT, provided SDCT protocols used on-farm culture systems or SCC-based selection, and internal TS was used in untreated healthy quarters.

The recent BDCT ban in the Netherlands resulted in a 36% reduction in AMU for DCT without major negative udder health impacts. However, there was a small increase (+0.41%) in high test-day SCC (heifers: > 150,000 cells/mL; older cows: > 250,000 cells/mL) and a new high test-day SCC (either at first test after calving, or a high SCC report after low SCC at previous test day during lactation) (+0.06%). Therefore, most herds can enact SDCT with minimal or no negative effects on udder health. Impacts of TS use are unknown, but from 2013 to 2015, TS sales in the Netherlands increased by 73%.

To summarize, considering udder health, SDCT is a viable option, with consistent reports of no negative effects on SCC after calving, elimination of udder infection, new udder infection risk, and presence of infection at calving. With appropriate selection criteria and other mastitis control procedures (i.e., TS and good overall hygiene) to reduce udder infection, SDCT can be used without negatively affecting udder health.

Milk Production

Although selection criteria and specific udder health impacts differed among studies considering SDCT impacts, most studies reported no difference between BDCT and SDCT for milk production in the next lactation. Although most studies reporting no effect on milk production included internal TS in their SDCT protocols, one study without TS also had no negative effects on milk production.

In an Irish study, low SCC cows (< 200,000 cells/mL throughout lactation) that received only internal TS had higher mean daily milk yield (0.67 kg) over the entire lactation, compared to low SCC cows getting both internal TS and antimicrobials in the udder. However, there are no other reports of similar findings for milk production.

Based on available literature, with selection criteria sensitive enough to identify most infected cows at drying off and use of TS to prevent new udder infections, negative milk production consequences can be avoided. However, further research is needed to better define relationships among SDCT, TS, and milk production.

Economics

Economic evaluations are country- or region-specific, due to variations in costs or milk prices (the latter differ between countries with or without supply management), the availability of low-SCC incentives, and other regional differences. In a U.S. study, SDCT was more economically beneficial than BDCT, and SCC-based SDCT was more economically beneficial than SDCT based on culture (mean costs savings/cow of US$7.85 versus US$2.14, respectively). However, DHIA SCC testing was assumed to be available, and no additional testing costs were included. Furthermore, economic impacts varied considerably. In a sensitivity analysis, economic advantages of SDCT were substantially lower if its implementation increased clinical and subclinical mastitis after calving. Although economic benefits of SDCT were highest in herds with lower CM incidence and BMSCC, all herd types can have reduced AMU at drying off without greater economic losses.

Economic impacts of SDCT likely differ among herds and management systems because of bacterial profiles, selection criteria, costs for antimicrobial treatments, and level of AMU reduction. Therefore, it would be useful to have general agreement on economic model development and coefficient inclusion, the ability to adapt economic analysis to farm-specific scenarios, and assumptions about ‘routine’ mastitis management strategies (i.e., pre- and post-dipping, culling of recurrent high SCC cows, bedding management, etc.). Therefore, economic models need to consider costs associated with evaluating current mastitis management practices and implementation of new management practices as required, rather than application of SDCT. Models must also be updated with real-world data supported by literature and be contextually specific while minimizing structural limitations of model development.

A partial budgeting tool can be adapted to a variety of herd contexts for individual producers to compare economic impacts of various DCT approaches. Here is an example of an interactive partial budgeting tool: https://dairyknow.umn.edu/research/udder-health/selective-dry-cow-therapy-cost-calculator/. Economic evaluations specific to various industry contexts are needed.

Additional considerations

Various factors impact drying off decision making and dry cow management, including social determinants of AMU, product availability, and cows’ physical environment. Administration of antimicrobials in the udder has some risk due to potential for contaminating the udder. Therefore, hygienic drying off practices and other management decisions are also important for overall dry cow wellbeing and for limiting udder infections. These include, but are not limited to, milk production at drying off (abrupt versus gradual reduction), nutrition, housing, culling chronically infected cows, dry period duration, and limiting udder infections during lactation to reduce udder infections at drying off.

Clinical Mastitis

Cattle health

Thirteen studies in North America, Europe, and New Zealand evaluated effects of selective and blanket CM treatment protocols. Short-term outcome measures included bacteriological cure and clinical cure, whereas long-term outcome measures included SCC, CM recurrence, and culling rate. Clinical cure is defined as absence of clinical signs; it is easy to observe and often used by farmers and veterinarians for treatment evaluation. In contrast, bacteriological cure is achieved when the causative agent is eliminated, providing a more reliable measure of antimicrobial treatment efficacy. No difference in bacteriological cure was reported between CM cases treated in a selective versus a blanket antimicrobial treatment protocol. Regarding clinical cure, a slightly higher proportion of cases that reached clinical cure within 14–21 days was observed in the selective treatment group, as well as 0.4 day longer time to clinical cure. These results were, however, influenced by co-administration of NSAID in selectively treated cows.

Regarding long-term outcomes, there was no difference in SCC after CM between selectively treated and blanket treated CM cases. Similarly, there was no difference in risk for recurrent CM cases in the selective versus blanket treatment groups, and no significant difference in culling rate and milk production.

Economics

Similar or lower costs have been consistently reported fora selective treatment protocol based on rapid diagnostic tests compared with a blanket treatment protocol. Direct costs associated with selective treatment protocols include costs for analyzing milk samples (i.e., labor and testing plates). Potential benefits to selectively treating CM cases compared with blanket treating are reduced treatment costs and reduced days of discarding milk. Indirect costs include production losses due to CM and potential culling and replacement costs. Farms with a higher proportion of Gram-positive CM cases will have similar costs compared with farms with a blanket CM treatment approach.

Reduction of antimicrobials

Reductions in AMU achieved through bacterial identification-based selective CM treatment is determined by two factors: the initial distribution of bacteria of CM cases and CM incidence. If the majority of CM is Gram-negative or culture-negative, a selective CM treatment protocol will substantially reduce AMU. Reducing CM incidence also contributes to lower AMU. Therefore, udder health management needs to be optimized to reduce infection pressure by Gram-positive bacteria. There is also a lower risk of receiving a follow-up treatment for cases that are treated according to a selective CM treatment protocol. With knowledge of the presence of bacteria and the specific kind of bacteria, farmers may be less prone to initiate another antimicrobial treatment when there is no resolution of clinical signs.

▪ Antimicrobial Use Motivations

Despite literature supporting SDCT and selective CM adoption, it can be difficult to convince some producers and veterinarians to follow these approaches. To increase uptake, drivers and barriers to adoption of selective treatment strategies must be considered. For example, regulations and fines for ‘overuse’ can be introduced, but unintended consequences must be considered; for example, illegal AMU requiring constant enforcement, and animal welfare concerns. Furthermore, concerns of producers toward regulations are associated with increased AMU, and veterinary consultation for antimicrobial decision-making and treatment for antimicrobials routinely available to producers may be limited.

Producers

Although cattle health and welfare influence on-farm AMU, other factors for choosing antimicrobial treatments include producer practices and perceptions, previous experience, economic considerations including lack of time and resources, atmospheric climate, farm ‘uniqueness’, farm biosecurity, societal pressure, risk aversion, difficulty of implementing management changes, and a ‘moral’ duty to treat a sick animal. Concern for financial consequences and uncertainty regarding mastitis recovery without AMU were among the most important factors for producers choosing BDCT over SDCT. For CM treatment, concerns about reduced welfare when withholding treatment were often mentioned.

Existence and awareness of prudent AMU guidelines vary worldwide, with greater producer AMR knowledge and awareness in high-income countries. Skepticism has been identified regarding the degree to which agricultural AMU contributes to AMR, especially human health impacts, where awareness of the relationship between AMR in humans and agriculture was low. In a South Carolina study (2007), 86% of producers were not concerned that livestock antimicrobial overuse could cause AMR infections in farm workers. Minimal concerns regarding consequences of AMU may contribute to a lack of desire to reduce AMU. In contrast, in 2013, 70% of producers in the UK thought reducing AMU was a good idea.

Recent research conducted by our group in Alberta, Canada, identified that although producers were skeptical of a link between AMU in dairy cattle and AMR in humans, producers sought to act in the best interest of animals, humans, and the environment, and were committed to maintaining the integrity of their food product. While some producers identified as stewards of the land, they also valued their independence in AMU decision-making and hoped future AMU regulation would reflect their desire for on-farm autonomy. Further, Alberta producers believed their knowledge and experience are undervalued by consumers and policymakers and expressed concern that AMU policy will be based on misguided consumer concerns rather than being evidence based. Familiar with implementation of AMU policies in other contexts (e.g., the Netherlands), producers were knowledgeable about regulations that would not be well-suited for the community and instead were interested in initiatives tailored to farms in Alberta. Understanding the context of on-farm AMU decision-making is important to consider when striving for improved antimicrobial stewardship and critical in establishing long-term uptake by producers.

Selective DCT and selective CM education, training, and campaigns are important in changing producer perspectives and practices regarding mastitis management. However, successful communication of farm management improvement opportunities must acknowledge various producer perspectives, capabilities, opportunities, and learning styles. Producers motivated to improve udder health are most impacted by a ‘central route’ of information, including providing instruction cards, treatment plans, checklists, and software with rational arguments for change. In contrast, producers without initial behavioural change motivation were most impacted by a ‘peripheral route’ using a subconscious or indirect method without reasoning or rational arguments that focused on a single message (e.g., wearing gloves while milking). Both methods should be combined to optimize effectiveness of AMU reduction campaigns.

Crucial components of successful communication are a proactive approach, message personalization, provision to producers of practice-based examples, and use of social environment. Integration of science and producers’ knowledge and experience increases recommendation credibility and practicality, leading to measurable and lasting reductions in AMU.

Veterinarians

It is important to consider the perspective of veterinarians because they substantially influence producer AMU. Until recently, BDCT was endorsed by veterinarians in many countries, and some remain adamant in their support. Literature regarding attitudes and perceptions of veterinarians towards AMU and AMR generally indicates agreement on the importance of reducing AMU in livestock production. Antimicrobial prescribing behaviour of livestock veterinarians is dependent on multiple factors, including obligations to ease animal suffering, financial dependency on clients, risk avoidance, advisory skill limitations, producer economic limitations, lack of producer compliance, public health safety, and beliefs regarding degree of veterinary AMU contributions to AMR. Veterinarians consider economic drivers to be strongly correlated with producer compliance with veterinary recommendations.

In the Netherlands, views regarding SDCT differed among veterinarians. National policy was introduced in 2013 that determined that only SDCT could be used; many veterinarians agreed, but some felt they were endorsing a decision not aligned with their own beliefs of dry period risks. Most UK veterinarians interviewed preferred SDCT because it aligned with prudent AMU strategies. Regarding veterinary SDCT perspectives, there were three themes: 1) prioritizing prudent AMU and attempting to maintain producer engagement; 2) veterinary experience level and ability to influence producer decisions; and 3) veterinary perceptions about SDCT risks and implementation difficulties, which varied greatly. With increasing experience, veterinarians were less likely to consider veterinary contributions to AMR as a concern, whereas junior veterinarians were less likely to take a primary prescribing role or make suggestions contradicting senior colleagues, despite an expressed desire to assume more prescribing responsibility. Because senior veterinarians have greater influence on producer AMU, they should facilitate the transition from BDCT to SDCT, where prudent to implement, and increase producer trust of their junior colleagues to further optimize AMU decisions. Furthermore, initiatives to mitigate negative veterinary perceptions of SDCT risks and improve producer perceptions of the veterinary community as a ‘united front’ of SDCT support, will likely promote industry changes.

Changing veterinary perceptions and access to new information does not always progress logically. For example, although new data supporting TS use were accepted by most veterinarians, research conclusions close to their own beliefs were more readily accepted. Consequently, new data on SDCT and TS may cause uncertainty and doubt in decision making. Advocating SDCT instead of BDCT, the longstanding industry norm, is a considerable change from an udder health perspective. Therefore, it may take substantial evidence to convince more change-averse veterinarians to adopt SDCT.

Some UK producers and veterinarians felt their personal stewardship efforts were undermined by the actions of others, including other countries’ agricultural sectors, with specific blame on the human medical community. Previous research suggests increasing One Health stewardship efforts that are focused on individual knowledge and motivations may increase personal responsibility and reduce blame placed on others. The relationship between producers and veterinarians can either be a barrier or a facilitator of antimicrobial stewardship, depending on the dynamic, with producer-veterinary partnerships fostering shared responsibility and improved stewardship efforts. Promoting desired behavior change requires end users (i.e., producers and farm workers) to perceive that their actions regarding AMR are effective and important.

▪ Further Steps

With increasing scrutiny of preventive AMU and calls to decrease agricultural AMU worldwide, adoption of SDCT and selective treatment of CM can be expected to increase. Specifically, an industry ‘paradigm shift’ is required to transition from indiscriminate AMU to justified AMU based on presence or risk of an udder infection (DCT) or odds of cure (CM). As this shift occurs, it is worth considering how to facilitate sustained behaviour change using a holistic approach. It is important to integrate priorities of all relevant stakeholders in development of any public health initiative that will be both impactful and practical. Providing benchmarks of antimicrobial prescribing to veterinarians and producers may allow them to contextualize their antimicrobial prescribing and use compared to their peers, encouraging conversations regarding AMU practices. Overall, national SDCT and selective treatment of CM guideline development that consider country-specific industry differences, along with supportive veterinarians, and effective communications, would provide producers with tools to successfully implement SDCT and selective treatment of CM with limited negative consequences on udder health and productivity. This should be coupled with ongoing evaluation of AMU and impacts on AMR in the dairy industry.

Conclusions

Although described selection protocols and results differed, common themes emerged that support SDCT and selective treatment of CM. To improve chances of SDCT success, producers should be provided with various protocols (i.e., SCC or identification of bacteria), based on their access to data or willingness to choose one method over another, with TS considered an important part of the protocol. If SDCT recommendations are practical and based on producer situations, uptake will likely increase.

Not all CM cases benefit from antimicrobial treatment. Therefore, correctly identifying CM cases that do and do not benefit from antimicrobial treatment is key to support further judicious AMU in dairy farming. Herd characteristics and history as well as the individual cow should be considered in CM treatment, accompanied with a relatively fast crude identification of the organism causing CM. Various rapid field tests are available to provide presumptive identification of the causative organism and support treatment decisions. Most reports did not indicate negative economic or udder health consequences (e.g., clinical cure, bacteriological cure, SCC, culling rate, milk production, milk withdrawal time, or number of follow-up treatments) after initiating selective CM protocols using on-farm testing.

Using selective treatment protocols depends on legislation, management systems, and adoption of udder health control programs. The level of AMU reduction following selective protocol initiation depends on the distribution of bacteria responsible for the CM cases and percentage of quarters infected at drying off. Furthermore, ongoing producer and veterinary education is essential to increase antimicrobial stewardship in the dairy industry and increase personal responsibility in AMR mitigation. Proper evaluation mechanisms are needed to evaluate impacts of introduced SDCT and selective treatment of CM protocols. In summary, SDCT and selective CM treatment protocols can be used without affecting udder health and milk production, but reducing AMU and potentially reducing AMR.

References

Many studies were indirectly cited in the text, but there were too many to list. This manuscript is a shortened version of two invited reviews on DCT (McCubbin et al., 2022) and another on selective treatment of CM (De Jong et al., accepted). Because Journal of Dairy Science is an open access journal since January 2022, these manuscripts will be freely accessible once published. An additional manuscript on the effects of selective treatment of CM on cure, SCC, recurrence, and culling is in press in Journal of Dairy Science (De Jong et al., in press). Finally, a manuscript on the perspectives of Alberta dairy farmers on AMU is also in press (Ida et al., in press).

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Prevention and control of *Salmonella* in dairy cattle

Luc Bergeron, D.M.V., M.Sc.

Animal Health Department, Quebec Ministry of Agriculture, Fisheries and Food, 200, chemin Sainte-Foy, 11th floor, Quebec City QC G1R 4X6
Email: luc.bergeron@mapaq.gouv.qc.ca

Take Home Messages

- Salmonellosis is an important cause of disease in cattle and in humans, and is a major public health concern.
- In the last decade in Canada, the emergence of *Salmonella* Dublin has become a major concern for the dairy cattle industry.
- To help prevent and control *Salmonella* infections in cattle, the exposure to the bacteria needs to be minimized and the disease resistance needs to be maximized.
- In recent years, a significant proportion of the *Salmonella* strains that have been isolated were resistant to one or more antibiotics, particularly for *Salmonella* Dublin and *Salmonella* Typhimurium. Antimicrobial resistance is a major concern for animal health and public health.

Salmonella in Dairy Cattle

Salmonellosis is an infection caused by a bacteria called *Salmonella*. It affects most animal species and humans and is a major public health concern. There are more than 2,500 serotypes of *Salmonella*, but only a few of them are of clinical importance in cattle. In North America, the most frequently isolated *Salmonella* serotypes in cattle include Dublin, Cerro, Newport, Montevideo, Kentucky, Typhimurium and Muenster. Some of these serotypes, most notably Dublin and Typhimurium, are more virulent than others and will cause more severe clinical disease. The United States Department of Agriculture's National Animal Health Monitoring System Dairy 2007 study estimated that 40% of the dairy cattle herds had at least one cow positive for *Salmonella* on a fecal culture and that 14% of the cows sampled were positive.

As for many other enteric diseases, the usual route of infection is fecal-oral. In dairy cows, infection generally occurs when they ingest feed or water contaminated by feces. *Salmonella* may be introduced in a herd from purchasing infected cattle or contaminated feed. Birds and rodents are also sometimes identified as a source of introduction. When cattle are infected with *Salmonella*, the infections can range from subclinical to systemic. Clinically affected adult cows and calves will generally present with diarrhea, and sometimes with blood, fever, dehydration, and depression. In some instances, particularly in calves, when the bacteria enter the blood stream and cause a bacteremia, they can infect organs other than the intestinal tract and cause other clinical problems such as septicemia, pneumonia, arthritis, and meningitis. In adult cows, it can also cause abortions. More information on *Salmonella* in dairy cows can be found in Holschbach and Peek (2018).

For cattle with salmonellosis, supportive therapies, such as oral or intravenous electrolytes and fluids, are generally recommended. The use of antibiotics to treat salmonellosis is controversial and antibiotics should only be used when justified. For enteric salmonellosis, antimicrobial therapy is not justified, but it can be when the disease is more severe and systemic.

In the last decade in Canada, the emergence of *Salmonella* Dublin has become a major concern for the dairy cattle industry. When cattle are infected with *Salmonella* Dublin, the bacteria will more often than for other serotypes enter the blood stream and cause a bacteremia, and generally, a more severe clinical disease. *Salmonella* Typhimurium is another serotype that can sometimes enter the blood stream and cause a systemic disease. The other major concern with *Salmonella* Dublin is that this serotype is host adapted in cattle, which means, in some cases, it can cause a lifelong infection. These chronically infected cattle will become asymptomatic carriers and will shed the bacteria intermittently in their environment. This can be challenging in terms of prevention and control of the disease.

▪ What Can I Do to Protect My Dairy Cattle Herd?

Cattle with subclinical infections will shed low numbers of bacteria, whereas infected animals that are sick and are presenting clinical signs may excrete higher numbers in their feces. When a calf or adult cow is infected the factors that determine if the animal will become sick and show clinical signs include the virulence of the serotype, the dose of bacteria that the animal is exposed to, and the level of immunity of the animal. In other words, to help prevent and control *Salmonella* infections in cattle, the exposure to the bacteria needs to be minimized and the disease resistance needs to be maximized.

The following are good practices that can be implemented in a dairy cattle herd to minimize the exposure to *Salmonella*:

- Implement strict biosecurity practices to prevent introduction of *Salmonella* or other pathogens into the herd. These measures should be implemented for employees, visitors, vehicles, and equipment. For employees, biosecurity practices should be implemented when moving between groups of animals or other specific areas like the feed storage, the calving area, or the animal hospital.
- Place newly introduce animals in isolation or maintain a closed herd.
- Implement strict hygiene practices. Keeping the pens and alleys clean and dry is particularly important. When possible, clean and disinfect the premises periodically. Clean and disinfect equipment between use.
- Prevent contamination of feeds and water sources by feces of cattle, rodent, birds, and other animals. Implement a control program for rodents and birds.
- When a *Salmonella* infection is suspected or confirmed:
  - Place suspected of infected animals in isolation.
  - Clean and disinfect the premises, particularly the area where the infected animals were housed. Clean and disinfect equipment between use.
- Specifically for *Salmonella* Dublin:
  - Use serologic screening testing before introducing a new calf or cow into the herd. Ensure a negative serologic status from the herd of origin or, if not available, a negative serologic test from the individual animal.
  - Use serologic screening testing to identify asymptomatic carriers.
  - For a cow suspected to be an asymptomatic carrier, separate the newborn calf from the cow as soon as possible following calving and feed the calf with a colostrum replacer.

The following are good practices that can be implemented in a dairy cattle herd to maximize disease resistance:

- Maintain good general cattle health. Particular attention to the health of late gestation and early lactation animals is critical. The good health of calves is also important because they are more susceptible to severe systemic salmonellosis.
- Prevent herd stresses. Provide adequate comfort, temperature, animal density and feed.
- Ensure good colostrum management.
- Implement a herd vaccination program with the recommended core vaccines.

The implementation of the practices listed above should be discussed with the herd veterinarian.

What Can I Do to Help Protect Public Health?

Salmonellosis not only can cause disease in cattle, but also poses a significant zoonotic risk. In other words, this disease can be transmitted by animals to humans. Even though humans can be contaminated following direct contact with an infected animal or its environment, the most probable source of infection for humans is an exposure to contaminated meat or milk. These food-borne risks can be mitigated by proper handling and cooking of the meat and pasteurisation of the milk.

The recent emergence of *Salmonella* Dublin has also become an important concern for public health. As in cattle, the bacteria will more often than for other serotypes enter the blood stream and cause a bacteremia, and generally, a more severe clinical disease in humans.

As mentioned earlier, the use of antibiotics to treat salmonellosis is controversial and should only be used when justified. In recent years, a significant proportion of the *Salmonella* strains that have been isolated were resistant to one or more antibiotics, particularly for *Salmonella* Dublin and *Salmonella* Typhimurium. Antimicrobial resistance is a major concern for animal health and public health.

The following are good practices that can be implemented in a dairy cattle herd to help protect public health:

- Implement the good practices listed above to prevent and control *Salmonella* infections in cattle.
- Prohibit or limit visits of the herd by those most vulnerable to zoonoses, including pregnant women, young children, the elderly, and those with weakened immune systems.
- Implement basic biosecurity practices for employees and visitors:
  - Ensure that they wash their hands with warm water and soap before and after a visit of the herd, particularly after contact with animals and before eating or touching their mouths with their hands.
  - Ensure that they change their boots and clothes before and after a visit of the herd.
- Maintain high standards of milking hygiene. Most of the bulk tank milk where *Salmonella* is isolated is contaminated following indirect contact with contaminated feces during the milking process. When cattle are infected with *Salmonella*, the bacteria are rarely shed directly in the milk. Direct shedding in the milk is more often reported with *Salmonella* Dublin than for other serotypes.
- Consult the herd veterinarian when cattle are suspected or confirmed infected with *Salmonella* before initiating any antimicrobial therapy to ensure that it is justified.

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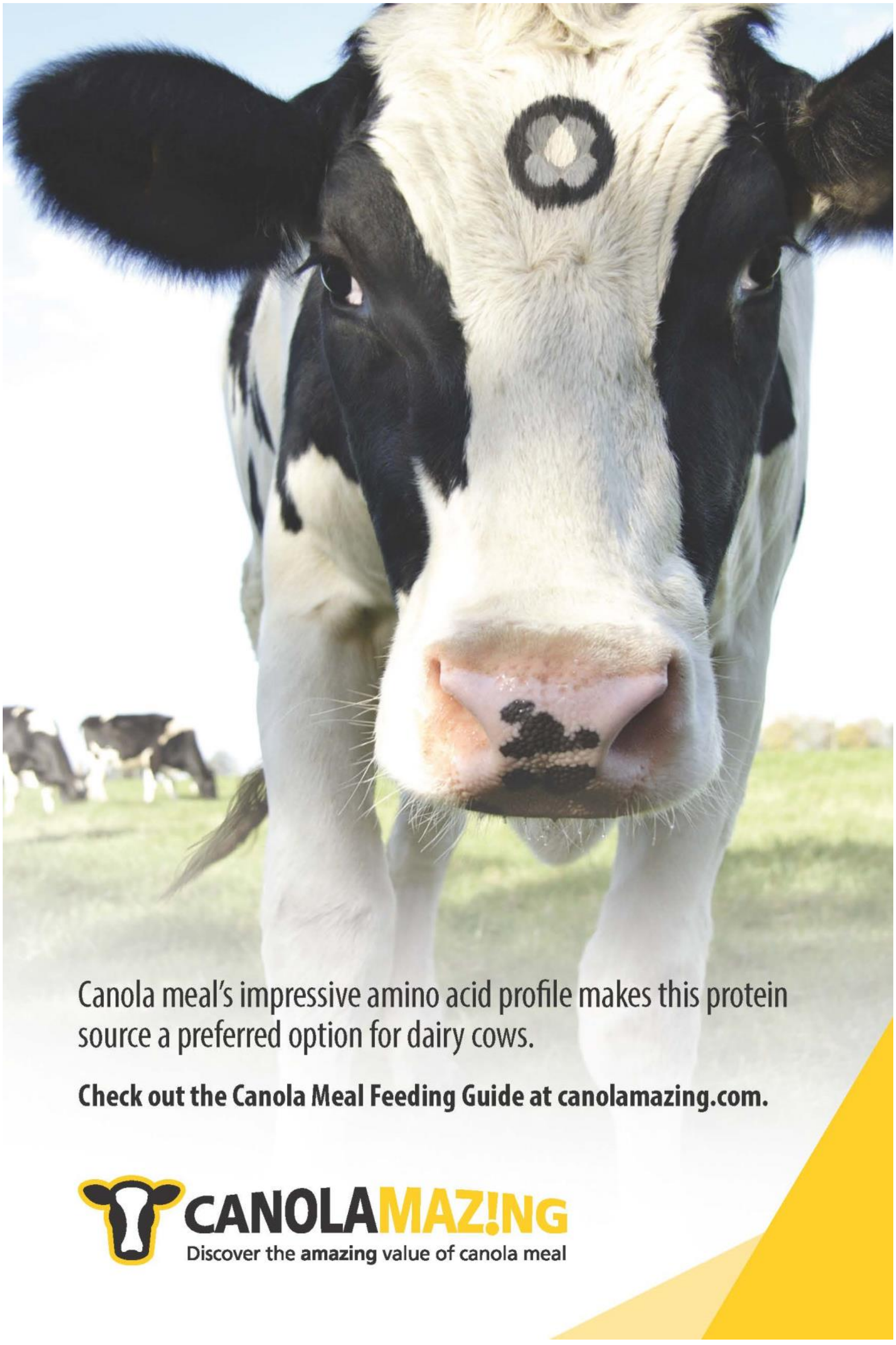
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Starting Calves Off Right: Back to the Basics on Colostrum Management

Sarah D. Parsons

Alta Genetics Inc., Rocky View County, Alberta.
Email: sarah.parsons@altagenetics.com

Take Home Messages

- Colostrum management on day one is the most critical management step in a calf's life in determining its health and longevity.
- Calves must be provided with large volumes of high quality colostrum early in life (< 2 hours of life) that has low bacterial contamination and is free of disease-causing pathogens.
- When quality of colostrum is low, supplementation with colostrum replacer is a viable option.
- Monitoring the colostrum program through measuring transfer of passive immunity is a requirement of sound colostrum management.
- Shift goals for passive immunity levels away from failed transfer to successful transfer of passive immunity, maximizing the number of calves in the excellent passive immunity category while minimizing the number of calves in the failed category.
- Colostrum is much more than just immunoglobulins (IgG), with the other components playing roles in development, thermoregulation, and disease resistance of the calf.
- Prolonged or extended feeding of some colostrum or transition milk after the first day of life can provide health and growth benefits to calves during the period that disease challenges are common.
- Use of colostrum as a therapeutic for calf disease, specifically diarrhea, is a promising area that requires further research.
- Good nutrition and management after colostrum feeding is critical for supporting health and welfare of calves and allowing the calves to reach their genetic potential.

Introduction

Dairy calves are both a by-product and a critical part of the dairy industry. Because dairy calves are commonly reared away from their dam, producers have the responsibility of providing proper care and management of their calves. Over the past few decades, the importance of calf care has received more focus as management practices change and long-term impacts of early life nutrition have become more evident. Although early life management is known to have short and long-term impacts on calf health and survival, room for improvement continues. The high rates of mortality (5%) and morbidity (38.1%) that calves face in the first two months of life are concerning from an animal welfare and productivity standpoint and also from an economic and sustainability standpoint (Urie et al., 2018).

The largest factor for impacting health and longevity of calves is proper colostrum management. Due to the type of placenta that cows have, immunoglobulins do not transfer across from the dam to the calf in utero, leaving newborn calves with an underdeveloped immune system and very susceptible to disease and mortality. Therefore, calves must consume and subsequently absorb immunoglobulins, specifically IgG, to obtain successful transfer of passive immunity (TPI). Successful TPI is not as simple as feeding colostrum to calves; there are multiple factors surrounding colostrum management that impact if calves will absorb an adequate level of IgG to avoid failed transfer of passive immunity (FTPI). Well-managed colostrum feeding on day one and extending colostrum or transition milk feeding can help set calves up for a successful future, through helping them overcome disease and improving their development. This review will focus on the components of colostrum management, ways to ensure the feeding program is set up well and working, and the benefits of extending colostrum feeding post day one of life.

▪ Colostrum Components

It is common to think about immunoglobulins, specifically IgG, when colostrum is discussed because colostrum provides calves with passive immunity. Colostrum contains more than 100 times the immunoglobulins found in milk. Primarily IgG is focused on because it accounts for most immunoglobulins in colostrum (85-90%); however, IgM and IgA are also present in colostrum. The colostral IgG also has a local effect in the gastrointestinal tract (GIT) where it binds to pathogens to limit their adhesion and absorption. Additionally, IgG (majority IgG1) is absorbed across the ‘open-gut’ of the newborn calf to enter circulation and provide immediate protection as passive immunity (Carter et al., 2021). Due to this primary and important role IgG plays in the calf, colostrum management has focused on immunoglobulins.

However, colostrum is much more than just IgG, and the other components play roles in immunity, energy provision and biological processes such as hormone signaling. Additionally, the development and proper functioning of the calf’s GIT is stimulated and supported by colostrum consumption (Hammon et al., 2014). A recent review outlines the quantities of some bioactives in colostrum compared to that in mature milk and discusses the benefit of these bioactives to the GIT (Table 1; Carter et al., 2021).

There are natural antimicrobial components, such as lactoferrin, lactoperoxidase and lysozyme that are in abundant quantities in colostrum compared with that in mature milk. These natural antimicrobial components work to limit the bacterial growth and protect calves from sepsis. Additional components that aid in immunity include cytokines, neutrophils and macrophages. High levels of oligosaccharides, specifically sialylated oligosaccharides, are also found in colostrum; these prohibit the binding of *E. coli* and rotavirus in the GIT and reduce GIT inflammation. Also, these oligosaccharides also act as prebiotics, providing an energy source for good gut bacteria and help develop the gut microflora, specifically beneficial species such as *Bifidobacteria* and *Lactobacillus*. (Carter et al., 2021; Fischer-Tlustos et al., 2021)

Table 1. Concentration of bioactives in colostrum and mature milk and the benefit to gut immunity and development.

Colostrum Bioactive		Concentration			Benefit to the Gastrointestinal Tract
		Unit	Colostrum	Mature Milk	
Immunoglobulin G		g/L	81	< 2	Primary immunity contributor through pathogen binding in intestinal mucosal membrane and passive immunity when absorbed into the circulatory system
Lactoferrin		g/L	1.84	0.1	Sepsis prevention in infants. Binds to iron, preventing excess growth of bacteria, such as *E. coli* and *salmonella.*
Lactoperoxidase		g/L	0.011-0.045	0.013-0.030	Inhibitory effects on bacterial metabolism through suppression of oxidation in proteins.
Lysozyme		µg/L	140-700	70-600	Cell lysis caused by hydrolysis of β linkages in the cell wall of Gram-positive and Gram-negative bacteria.
Insulin		µg/L	65	1	Promotes cell growth in the small intestine.
Insulin-like growth factor-I		µg/L	310	< 2	Stimulates intestinal cell growth and epithelial development.
Insulin-like growth factor-II		µg/L	150	1	Stimulates intestinal cell growth and epithelial development.
Oligosaccharides		g/L	1	< 0.2	Reduces gut permeability and promotes gut microflora development.
Fatty Acids		g/L	64	39	Improves thermoregulation capabilities. High levels of PUFA decreases oxidative stress by reducing the oxidants and reactive oxygen and nitrogen species.
Cytokines	IL-1 β	µg/L	845	3	Anti-inflammatory capabilities through the neutralization of pro-inflammatory molecules. Specifically, INF- γ amplifies the capacity of phagocytic cells.
	IL-6		75	< 0.2	
	TNF-α		925	3	
	INF-γ		260	0.2	

From an energy and metabolism standpoint, colostrum contains bioactives such as insulin, insulin-like growth factor-I (IGF-I) and insulin-like growth factor-II (IGF-II) that help with glucose absorption, growth, and development of the GIT. Colostral fat is another very important component; colostrum has a high level of fat compared with that in mature milk, and the specific fatty acid (FA) profile of colostral fat may play a role in thermoregulation. Newborn calves are born with brown adipose tissue (BAT) as their predominant fat reserve; however, the quantity is small, with only about 2% of their body weight (BW) being BAT (Silva and Bittar, 2019). The BAT is a critical component in thermoregulation in newborns, but with the small amounts in calves at birth, calves have a very limited ability to thermoregulate. Colostral fat is thought to act as a substrate for calves to use their BAT to thermoregulate and help warm them up or cool them down in events of cold or heat-stress (Silva and Bittar, 2019). Additionally, colostral fat plays roles in metabolism and can help with immune response in the first few weeks of life (Fischer-Tlustos et al., 2021). Colostral fat clearly plays very important roles in the newborn calf, further stressing the importance of ensuring proper colostrum feeding to optimize performance and survival. Research is beginning to investigate aspects of the FA profile of colostrum and how specific FA impact the calf, such as how supplementing omega-3 fatty acids may help reduce inflammation (Opgenorth et al., 2020). However, more work is required to understand if the entire FA profile of colostral fat is required for the immune response and thermoregulation processes, or if supplementing with a similar FA profile would be sufficient. Recently, a trial investigated the impact on calf performance when calves were fed either a biological (full fat) level of colostral fat (22% fat) or a low level of colostral fat (5.7%). The researchers concluded calves fed the full fat colostrum had increased BW and growth rates at 90- and 127-day measurements and tended to have half the level of respiratory issues compared with calves fed the low fat colostrum (M. Nagorske, personal communication). This is an important area to understand further, because some colostrum replacers lack or have low quantities of colostral fat, which may negatively impact biological processes and calf health. Overall, the bioactives in colostrum all have some role in the development, metabolism, or immune system of a calf. It is important to understand the power of colostrum and the impact it has on short and long-term development and performance, as proper feeding of colostrum is not solely about acquiring successful TPI.

Factors of Day One Colostrum Management

There are four factors to a colostrum management program that are important in helping avoid FTPI in calves. These factors are quickness, quantity, quality, and cleanliness, and all have recommendations that should be met. The recommendations for these factors are not arbitrary and are also not independent, as they all intertwine and if one is severely lacking, surpassing the recommendation in another still may not prevent FTPI. These 'gold standard' recommendations for colostrum programs are based on calves achieving successful TPI. Historically the cut-off for TPI was defined as serum levels of IgG ≥ 10 g/L, which was estimated to be achieved through providing calves 150 to 200 g of IgG early in life. However, from recent knowledge of improved morbidity levels from achieving a greater level of passive immunity, which will be discussed later in this paper, this IgG minimum has doubled. The goal is to achieve excellent TPI (≥ 25 g/L of serum IgG; see category descriptions later in the paper) to reduce the level of disease; this means calves should be fed a minimum of 300 g of IgG within the first two hours of life, or 400 g of IgG in the first 24 hours of life (Lombard et al., 2020). With high morbidity levels threatening the health and welfare of calves, farm economics and public perception of the dairy industry, it is crucial we shift away from avoiding FTPI and shift towards maximizing the percentage of calves that can obtain this excellent TPI level to help reduce morbidity levels. This movement of the goalpost for passive transfer can seem drastic when you look at doubling the recommended grams of IgG fed but can be met if all factors of colostrum management are refined and optimized.

Quality

One of the main factors that impacts the grams of IgG fed to calves is the quality of colostrum. Typically, quality of colostrum is referred to as grams of IgG per litre, and good quality has been defined as > 50 g/L of IgG (Godden et al., 2019). An easy on-farm measurement of quality is measuring the Brix percentage of colostrum using either an optical or digital refractometer. Brix and IgG concentration measured through the gold standard radial immunodiffusion (RID) analysis correlate well together (r = 0.75), making Brix % a good on-farm management tool. Typically, 50 g/L of IgG correlates to 21-22% Brix (Bielmann et al., 2010; Quigley et al., 2013), and is the minimum recommended cut-off. However, this cut-off was developed when avoiding FTPI was the goal, rather than the new goal of achieving excellent TPI. This raises the question of potentially increasing this minimum Brix % to ensure calves are getting a larger IgG dose via colostrum. Recent work conducted in Quebec supports the concept of increasing the Brix cut-off; calves that were fed colostrum that was ≥ 24.5% Brix were 2.9 times more likely to have successful TPI (Morin et al., 2021). Previous cut-offs for quality colostrum around 22% Brix were established by comparing Brix with IgG concentration determined by RID to achieve 50 g/L, rather than levels to avoid FTPI. Therefore, it is probable that the Brix cut off should be 24-25 % to avoid FTPI, rather than 22%, which also aligns with the increase in IgG required for excellent TPI. Additionally, feeding a higher level of Brix % colostrum is more critical when one of the other factors is lacking, such as a lower quantity fed or extended time to feeding. Many factors can influence colostrum quality, such as parity, breed, dry cow diets, dry period length, vaccination protocols and seasons (see Godden et al., 2019 review). Therefore, it is important that all colostrum be measured for quality using a refractometer before feeding every calf. An option when quality is lacking is to supplement or enrich the low-quality colostrum with a colostrum replacer to allow the use of low-quality colostrum while maintaining similar TPI levels (Williams et al., 2014; Lopez et al., 2020). Additionally, assessing thickness and color of colostrum is not an accurate way of determining quality, and for a small investment, measuring colostrum quality using a refractometer can help calves achieve excellent TPI levels and provide peace of mind to producers.

Quantity

The other main factor that impacts TPI in calves through directly impacting the amount of IgG fed is quantity of colostrum fed. The recommendation is to feed 10-12% of the calf's BW in colostrum for the first feeding, which equates to 3 – 4 L for a Holstein calf and 2 – 3 L for a Jersey calf. This provides calves high levels of IgG when their efficiency of absorption is maximized early in life. Providing large volumes of colostrum at the first feeding can increase serum IgG levels, average daily gain (ADG), and milk production in the first two lactations (Godden et al., 2019). Although this one high volume feeding typically prevents FTPI if quality is sufficient, calves benefit from a second feeding to increase IgG levels (Fischer-Tlustos et al., 2021), specifically a second feeding in the first 12 hours of life (Hare et al., 2020). This is likely due to an increased IgG mass fed through two feedings while the gut is still permeable to IgG, suggesting a minimum of two feedings of colostrum should be completed within 12 hours.

Quickness

There are two aspects to timing when it comes to colostrum management: timing of milking and timing of feeding. The timing of milking in relationship to calving is important to maximize the bioactive amounts in colostrum. As time progresses, colostrum quality (g/L of IgG) decreases; cows milked at two hours after calving have the highest colostrum quality compared with cows milked at 6, 10 or 14 hours after calving (Moore et al., 2005). Additionally, as time progresses bioactive concentrations decrease, likely due to dilution of colostrum with mature milk (Carter et al., 2021), stressing the importance of adapting milk procedures to incorporate cows soon after parturition. The other part of timing is how quickly the calf is fed. This is related to gut closure of the newborn calf. The calf's gut is permeable to large molecules like IgG when the calf is born; this is referred to as an 'open gut'. As time progresses the gut closes and its ability to absorb IgG decreases rapidly and is estimated to be fully closed at 24 hours of life. The maximum apparent efficiency of absorption (AEA) occurs immediately following birth. The AEA can be calculated based on serum IgG levels, calf BW and the quality (g/L of IgG) and volume of colostrum fed. In general, AEA is a way of assessing how well the calf absorbed the quantity of IgG fed. The AEA varies between calves, with 69% of calves falling between 21 and 40% AEA, but AEA will range between 7.7% to 59.9% (Halleran et al., 2017). Fischer et al. (2018) indicated a large drop in AEA between feeding colostrum within the first hour of life (51.8%) compared with six hours (35.6%) and 12 hours (35.1%). This not only indicates the importance of quickness in feeding but indicates that maximum absorption occurs at birth and the decrease in AEA may not be as linear as once thought, considering no AEA difference was detected between 6 and 12 hours. With the large AEA drop between the first hour of life and six hours, the first feeding of colostrum should be < 2hours after birth of the calf. Additionally, earlier colostrum feeding results in quicker colonization of beneficial gut bacteria such as Bifidobacterium spp. and Lactobacillus spp., which can aid in gut health (Fischer et al., 2018).

A management practice that can help with the timing of feeding is the use of an esophageal tube feeder. Historically, it was thought that tubing calves their colostrum resulted in reduced IgG absorption. Although there is some evidence of this, the volume that is being fed via esophageal tube must be considered because this colostrum will enter the forestomaches before it enters the abomasum and small intestine where it will then be absorbed. One study investigated IgG absorption differences when bottle or tube feeding colostrum and concluded that if the volume is sufficient (≥ 3 L), the IgG levels of the calves were similar (Desjardins-Morrissette et al., 2018). Because tube feeding allows colostrum to be administered quickly, it is a sufficient method of colostrum administration if done properly with clean equipment.

Cleanliness

Bacterial contamination of colostrum dramatically reduces colostrum quality and absorption because the bacteria may bind to the IgG in the gut and may also block the absorption of IgG across the intestine, reducing passive immunity. Additionally, the bacteria can be absorbed into the circulatory system, leading to disease. The recommendations for bacteria levels are < 100,000 colony-forming units (cfu)/mL total plate count and less than 10,000 cfu/mL total coliform count (Godden et al., 2019); however, these are quite high recommendations, and it is best to aim for lower bacteria levels. Many colostrum samples will exceed these levels of bacterial contamination, ultimately reducing IgG absorption and potentially making calves sick if fed. Contamination can occur during colostrum harvesting, storage and feeding. It is important that good milking procedures are followed, with all collection, storing and feeding equipment properly cleaned and sanitized, as these are common sources of bacterial contamination. If storing colostrum for a later date, cool the colostrum down as quickly as possible (within the hour), and place it in the refrigerator for a maximum of two days or freeze it immediately. Bacteria multiply extremely quickly in warm temperatures, meaning the bacteria level will double in freshly milked colostrum in only 20 minutes, so the colostrum needs to be fed or cooled and stored immediately after collection. Additionally, when thawing or heating colostrum, you need to ensure that it is not rushed, and overheating is avoided. If colostrum exceeds 60ºC, denaturation of IgG can occur; therefore, the water bath to thaw or heat colostrum should be below this temperature and should be changed frequently to maintain its temperature. Another thing to consider for cleanliness is the presence of pathogens that are of concern in the herd, such as *E. coli, Salmonella sp.,* and *mycobacterium avium paratuberculosis* (MAP- causative agent of Johne’s disease). If you have diseases of concern in your herd or specific cows that you know are positive for a disease of concern, consider discarding their colostrum, using a colostrum replacer, or investing in a pasteurizer.

Pasteurizing colostrum is becoming more popular on farm, and if feeding raw maternal colostrum, investing in a pasteurizer should be considered. Pasteurizing colostrum should be completed at 60ºC for 60 minutes to reduce bacterial contamination and inactivate disease-causing pathogens while minimizing denaturing of IgG. Feeding pasteurized colostrum can increase AEA likely due to lower levels of bacteria interfering with the IgG in the gut, reduce the risk of diarrhea, and promote GIT colonization of beneficial gut bacteria compared with feeding raw maternal colostrum (Godden et al., 2019). However, pasteurizers need to be managed well and calibrated frequently. If the quality of colostrum is poor before pasteurization, it will still be poor after. Pasteurization will not make gold out of garbage and the colostrum still needs to be tested for quality and bacteria level still needs to be considered. Also, if temperature is high, denaturation of IgG can be severe (up to 58.5 % in large batches; Godden et al., 2003). The effect of heat treatment on the other bioactives in colostrum is an area that needs more research. The temperature should be monitored frequently when pasteurizers are at the maximum temperature. Samples of batches of colostrum can be taken before and after pasteurization and monitored for IgG concentration to determine if the pasteurizer is running too hot and denaturing IgG. Although Brix % of colostrum is a good way to measure colostrum quality on-farm, measuring it before and after pasteurization will not indicate if the IgG are being denatured. Brix is a measure of total solids and not a direct measure of active IgG; therefore, if IgG denaturation is a concern, submitting pre- and post- pasteurization samples for IgG analysis through RID is recommended. Overall, pasteurizers are not a solution to poor management of colostrum and should be optimized to help programs when feeding maternal colostrum.

▪ Calves at Increased Risk for FTPI

Although the above recommendations for the quality, quantity, quickness, and cleanliness will likely result in TPI for most calves, there are still calving situations that create calves that are high risk for FTPI. Calves that experience stress, whether in utero, during birth or shortly after parturition, are susceptible to reduced AEA. Undergoing a long and difficult birth commonly results in postnatal respiratory acidosis in calves and is associated with a decrease in IgG absorption for the first 12 hours of life (Godden et al., 2019). Calves born under cold-stress conditions or after having a hard calving tend to have reduced vitality and will likely consume lower amounts of colostrum; therefore. they may require manually feeding (Murray and Leslie, 2013). Additionally, when born in heat or cold-stress situations, calves need to have colostrum administered immediately to allow thermoregulation to occur. Calves that are born from a dam that experienced heat-stress in her final trimester have an in-utero programming effect occur that reduces their ability to absorb IgG, while also reducing the dam's IgG concentration in colostrum (Dado-Senn et al., 2020). These calves will also go on to produce less milk in the first two lactations; therefore, it is critical they also do not experience FTPI (Dado-Senn et al., 2020). Additionally, as hours pass before colostrum feeding, calves are at an increased risk of FTPI. Therefore, calves that have extended time to feeding or are born overnight and found the next morning require high volumes of very high quality of colostrum to help overcome the decrease in AEA that occurs as time progresses. Calves that are at a higher risk of FTPI should have a separate colostrum protocol in place that provides them with higher quantities of IgG since their absorption capacity may be compromised. Feed these calves with very high-quality maternal colostrum (25-30% Brix) in large volumes or with a colostrum-derived replacer to eliminate bacterial contamination and ensure calves are fed quickly.

▪ Updated Recommendations for Monitoring Colostrum Programs

Ensuring the factors of colostrum management are followed will help reduce the incidence of FTPI and increase the TPI levels in calves. When calves experience FTPI, they have reduced growth and feed efficiency, are more susceptible to disease and death, and have reduced lactation performance and increased culling risk (Godden et al., 2019). Historically, the threshold for FTPI was developed around reducing mortality rates and was found to be < 10 g/L of serum IgG when measured between 24 and 48 hours. However, recently calf experts came together to investigate a four-category system to classify TPI levels, presented in Table 2.

Table 2. Updated recommendations for passive immunity levels when measured between 24 and 48 hours of life

Category	% of calves in each category	Serum IgG (g/L)	STP (g/dL)	% Brix of Serum
Poor (FTPI)	< 10	< 10	<5.1	< 8.1
Fair	~20	10 – 17.9	5.1 – 5.7	8.1 – 8.8
Good	~30	18 – 24.9	5.8 – 6.1	8.9 – 9.3
Excellent	> 40	≥ 25	≥ 6.2	≥ 9.4

These updated recommendations were developed to be achievable and to reduce morbidity and mortality rates. Calves in the excellent category had the lowest percent of morbidity compared with all other categories, suggesting that having a dichotomous pass versus fail monitoring system should be changed to reduce the disease calves experience (Lombard, 2020). As indicated in Table 2, there are a few ways of measuring TPI in calves through sampling their serum. Serum total protein (STP) and serum Brix are indirect, easy on-farm measurements when feeding maternal colostrum that offer producers, consultants and veterinarians ways of monitoring colostrum programs. However, when feeding colostrum replacer, STP and serum Brix are unreliable measurements and IgG concentration must be assessed directly through RID analysis conducted in a laboratory setting. As seen in Figure 1 (Lopez et al., 2021), STP and IgG levels in serum of calves fed colostrum replacers are not well correlated, likely due to different manufacturing and nutritional compositions of the different products.

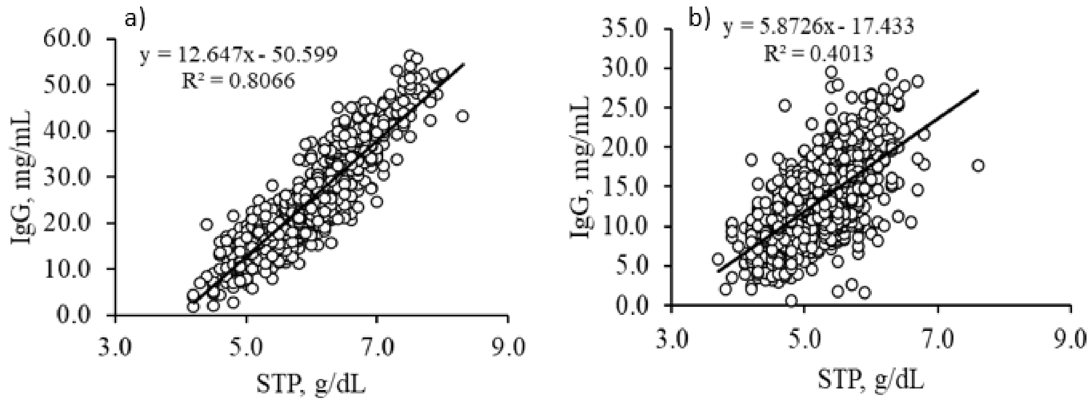

Figure 1. Linear regression relationship between serum total protein (STP) and serum IgG for 927 calves fed maternal colostrum (panel a) or 1,258 calves fed colostrum replacer (panel b).

If any type or amount of colostrum replacer is fed in the first day of life, blood samples should be sent to a lab for RID testing as this is an accurate way of determining IgG for these calves and is the gold standard of IgG analysis. Additionally, STP and serum Brix % should only be used on a population basis, measuring a group of calves rather than an individual only. Although RID and STP results are ~80% correlated, there is still room for error, meaning indirect measurement of IgG through STP or serum Brix % can misclassify calves Therefore, if STP results and calf health and performance are not aligning, samples should be submitted for RID analysis to ensure colostrum is not an issue. Recently, Cantor et al. (2022) investigated the impact of sampling time and classification level of TPI for calves during the first seven days of life. They concluded that IgG TPI level should only be measured between 24 hours to three days after colostrum feeding to avoid misclassification of TPI level due to the rapid degradation of IgG in the blood. Also, as TPI level recommendations are based on sampling blood at 24 to 48 hours, caution should be used when sampling after two days of life, as STP and IgG correlation can be variable and decrease over time, and dehydration levels impact STP values.

Prolonged Colostrum or Transition Milk Feeding

It is clear colostrum feeding is important for health and performance of young calves. However, as previously mentioned, calves continue to face high levels of morbidity and mortality during the preweaning phase. Digestive issues (i.e., diarrhea) and respiratory issues (i.e., pneumonia) are the two main causes of disease in young calves accounting for 56% and 33%, respectively (Urie et al., 2018). Diarrhea and pneumonia both have negative impacts on short-term welfare and performance and long-term production and economics. When calves experience diarrhea, they are more susceptible to other diseases, experience reduced ADG, and may experience death as a result. Long-term, calves that experience diarrhea have an increased number of inseminations to achieve pregnancy and can have over a 300 kg reduction in their first lactation milk yield (Carter et al., 2021). Additionally, when calves experience a respiratory event, they also have reduced ADG and increased risk of being culled before calving and may have reduced production in the first lactation (Buczinski et al., 2021). It is evident that disease plays a huge role in economics and efficiencies on a dairy; therefore, opportunities to help reduce disease events, severity, and duration, and improve growth during the preweaning phase are needed to improve welfare and sustainability of the dairy industry.

Beyond the economics and welfare aspect, the use of antimicrobials is a growing industry and societal concern. Antimicrobials are often reached for in events of diarrhea, although they can upset the gut microbiota early in life and can kill off both pathogenic and beneficial bacteria, causing a GIT dysfunction (Carter et al., 2021). In some rearing situations, antimicrobials are provided to all calves prophylactically, which is an even greater concern. With the disease and death pressures calves face, and the need to reduce antimicrobial use, natural prevention and therapeutic options are necessary.

Benefits of extended feeding of transition milk or colostrum

Over the past decade, interest in the composition of colostrum and transition milk (milkings 2 to 6 after calving; typically, 1 to 4 days post-partum) and how feeding it can impact the calf has increased. Transition milk contains high levels of bioactive compounds compared with that in mature milk and is likely to have a beneficial impact on the calf's gut development and health, as calves would naturally consume this if raised alongside their dam. Feeding transition milk after initial colostrum feedings can lower the odds of being scored with an abnormal eye or ear and nasal score (Conneely et al., 2014), and can reduce the duration of diarrhea (Kargar et al., 2021), compared with feeding whole milk directly after colostrum. Additionally, feeding 2 L of pasteurized transition milk that is mixed with 4 L of whole milk per day for the first three weeks of life can improve BW in the preweaning phase and ADG in the postweaning phase (Kargar et al., 2021). These results indicate that additional transition milk feedings after colostrum can provide short-term health and performance benefits and a prolonged advantage in growth.

Although transition milk is advantageous to feed, it can often be a difficult thing to collect, store and implement into a feeding program compared with first milking colostrum. An alternative to feeding transition milk is feeding small amounts of maternal colostrum mixed with milk or milk replacer to mimic this transition milk. Some researchers mimic transition milk by feeding 50% of a meal in milk or milk replacer, and 50% of the meal with maternal colostrum (Pyo et al., 2020; Van Soest et al., 2020). Others have investigated a smaller dose for the first two weeks of life (Kargar et al., 2020b). Additionally, feeding a 50:50 mixture of colostrum and milk for the first three days of life improved ability of the calf to absorb nutrients by increasing villi length and surface area of the small intestine (Pyo et al., 2020). Additionally, feeding a 50:50 mixture of transition milk and milk replacer from day 2 – 4 of life improved growth and reduced signs of inflammation in calves (Van Soest et al., 2020). Producers may have a difficult time identifying these positive outcomes of feeding transition milk for a few extra days of life because many benefits are occurring within the development of the digestive system. Nevertheless, if feeding transition milk can be managed well, it may make for more efficient and healthier calves,

Although there are clear benefits to calf gut development when feeding transition milk or mimicking transition milk with maternal colostrum for a few days of life, the properties of colostrum bioactives may provide benefits over a longer period. Kargar et al. (2020b) showed that feeding pasteurized maternal colostrum (700 g/d) for the first two weeks of life resulted in reduced days with diarrhea, pneumonia, and high temperatures, and improved postweaning ADG and final BW. An alternative to using maternal colostrum is supplementing in a dried colostrum-derived replacer to avoid opportunities for error in managing raw transition milk or colostrum and ensure consistency in components day to day. Mimicking transition milk with colostrum replacer has been shown to reap the same benefits of improved growth and reduced inflammation compared with feeding transition milk (Van Soest et al., 2020). Offering calves 70 g/d of a colostrum-derived replacer (10 g of IgG) for 14 days improved feed intakes and growth and reduced diarrhea events and treatments (Berge et al., 2009). More recently, Chamorro et al. (2017), concluded that feeding 150 g (32 g of IgG) of colostrum replacer for 14 days can reduce abnormal fecal, respiratory, attitude and navel scores while reducing antibiotic use. Overall, there are gut development, health, and economic benefits to feeding transition milk or colostrum after the first day of life. However, research to date has primarily focused on calves fed lower planes of nutrition (~4-6 L/d) and understanding how these extended colostrum feeding programs can impact calves fed higher planes of nutrition is an area of interest as more producers shift towards this practice due to the benefits in health and production.

Opportunities for Colostrum as a Therapeutic

As indicated, the use of colostrum or colostrum replacer as a prophylactic treatment for the first 14 days of life seems promising to help reduce health issues and promote growth while reducing antimicrobial use. The use of hyperimmune colostrum, created by exposing dams to specific pathogens to ensure high levels of antibodies for that pathogen in her colostrum, has been used in the past for diarrhea treatment in humans, mice, and calves (Carter et al., 2021). Although a viable option, economically and from a welfare standpoint it is not likely sustainable or overly efficacious, as calf diarrhea is multifactorial, and calves are often faced with more than one pathogen. Cantor et al. (2021) used drinking behavior (reduction in drinking speed or intake) from day 14 to 50 to identify calves that may be experiencing a health event. These calves were then fed a meal of 125 g of milk replacer or 125 g of colostrum replacer for three days. The authors concluded that calves fed the colostrum replacer meal had reduced odds of getting bovine respiratory disease and lung consolidation in the following weeks. Recently, Carter et al. (2022) investigated the efficacy of colostrum as a diarrhea treatment for calves and concluded feeding a 50:50 mixture of milk replacer and colostrum replacer for four days or eight milk feedings helped calves get over diarrhea more quickly and improved their growth rates, compared to keeping diarrhetic calves on milk replacer. These are promising results that indicate colostrum may be a good option as a therapeutic when there are early disease symptoms however, further work is needed to identify dosing, timing, and duration of these treatments to get optimal results.

Summary

When thinking about colostrum, we need to continue to shift away from solely focusing on IgG. Further exploration of the different bioactives in colostrum and the role they play in the calf is required. Focusing on ensuring day one colostrum management is done properly, with all calves consuming adequate volumes of quality colostrum in the first few hours of life is the most important area of calf management to promote health and performance both short and long-term. However, the focus on colostrum feeding shouldn't end after two feedings on day one, and some level of transition milk or colostrum should be fed for an extended period. There are promising results and interest in using colostrum to treat health events, specifically diarrhea, which would be beneficial to the calf, producer, and sustainability of the industry. Although colostrum is the most important step in calf care, and extended feeding of colostrum can help calves overcome disease challenges and optimize their growth and GIT development, milk and solid feed nutrition, housing conditions and management of calves all play a role in calf performance. Setting calves up for success through good colostrum management is the first step, but certainly not the last, and guaranteeing adequate nutrition and management are provided thereafter will ensure the calves are thriving, and ultimately will generate better milk cows for the future herd.

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Optimizing Health and Welfare in the Pre-weaned Calf: Housing and Management Practices

Charlotte Winder, DVM, DVSc

Dept. of Population Medicine, University of Guelph, Guelph, ON, N1G 2W1, Email: winderc@uoguelph.ca

▪ Take Home Messages

- Calves reared in group or paired housing during the pre-weaning period have improved social development, which can have lifelong benefits.
- Group or pair-housed calves don't have to have increased disease or cross sucking, if the environment and colostrum program are well-managed.
- Deep bedding with long straw both helps calves stay warm in the winter and reduces risk of respiratory disease.
- If housing calves indoors, a positive-pressure ventilation system supplemented with natural ventilation can ensure adequate air exchange without drafts.
- Calf vaccine programs are important for health, but can't overcome poor environmental management, and should be designed in consultation with your herd veterinarian.
- Disbudding should be done well ahead of weaning, and at a time when pre-weaned calves are healthy and vigorous.
- Regardless of method, disbudding pain control should include both a local anesthetic and an NSAID analgesic.

▪ Housing

Cattle are naturally social animals, and several studies have shown that calves reared in isolation have trouble adapting to new situations and may be more fearful or avoid new objects or feeds, compared with those reared with at least one other calf (Costa et al., 2016). Group or pair housing improves social development and can decrease the stresses associated with weaning. Weaning is often accompanied by other stressors such as changes in pen, group size, and feed type and feed access. Calves reared in group or paired housing pre-weaning have been shown to adapt better to these changes (Van Os et al., 2021) which can mean lower risk of disease and improved growth and development, leading to improved milk production (Costa et al., 2016). Challenges of group housing include potential increase in disease risk, and abnormal behaviours such as cross sucking. However, these can be limited or eliminated with careful management around colostrum, bedding, nutrition, and disease monitoring (Van Os et al., 2021).

Ideally, stable groups (not continually adding or removing calves from a group) using 'all-in-all-out' can benefit calves by not exposing younger calves to older calves who may carry disease causing agents, and because the pen can be cleaned and left to dry between groups, breaking the cycle of infectious agents (Nordlund and Halbach, 2019). However, this is often difficult to accomplish on the average Canadian farm based on the number of calves born per week. With a continual flow system, calves can still achieve excellent health and growth when other aspects of management (e.g., nutrition, bedding, ventilation) are optimized.

For group housed calves, smaller (ten or less) and more stable groups (not continually adding or removing calves from a group) have less disease than larger groups with continuous flow of calves in and out (Van

Os et al., 2021b). However, larger groups of up to 20 can likely be managed well if other aspects of housing, like stocking density, appropriate meal size and daily allowance, are well managed (Nordlund and Halbach, 2019). It is generally recognized that there is a higher risk of disease as group size increases. For smaller farms, or those unable to accommodate group housing, pair housing is an alternative that can provide social benefits without the challenges associated with groups of varying age. Besides having individual group pens, farms can modify outdoor housing by connecting the outdoor space around two individual calf hutches with wire or corral panels. Alternatively, as calves will prefer to lay together in the same hutch, group or super hutches can be used that provide more square footage, but care must be taken in the winter as the opening is larger (Van Os et al., 2021a). Super hutches generally provide 60 square feet of bedded space, appropriate for two calves (Van Os et al., 2021a). Ideally, pairs should be started earlier in life; one study found that calves paired at six days of age outperformed calves not paired until 43 days of age (Costa et al., 2015). Indoor paired housing can be created by removing the divider between two pens (Figure 1).

Figure 1: Pulling dividers is an easy way to accommodate pair housing in a calf barn.

For indoor housing, stocking density has an enormous impact on air quality and subsequently, on calf health. Based on studies focusing on airborne bacterial loads, industry experts recommend a minimum of 35 square feet of bedded area per calf (Nordlund and Halbach, 2019). Total airspace should also be considered, with a goal of at least 600 cubic feet per calf.

▪ Bedding

Air quality is important to assess at the calf level. Although the air quality might be good in the middle of an alley, depending on the barn’s ventilation, air quality at the calf level might be quite different. Calves spend the majority of their time laying down, so air quality at the level of the bedding can have a big impact on calf health. Long straw is associated with improved health outcomes in preweaned calves compared with other bedding types (Renaud et al., 2018), and improves gains in the winter compared with shavings (Hill et al., 2011). Benefits of using long straw to bed calves include, when done with deep bedding, an improved microenvironment at the calf level (better air quality) and also more insulation value in the winter. To achieve these, deep bedding must be used. The University of Wisconsin developed a score called the ‘Nesting Score’ to evaluate if bedding is sufficient in winter. When a calf lays down, if you can see the hoof and entire leg, it is a score of 1. If you can see the knees and hocks, but not the lower leg, it is a score of 2. When the hocks and knees are not visible when the calf is laying, it is a score 3 (Figure 2). A Wisconsin study demonstrated that having a bedding score of 3 dramatically reduced the prevalence of respiratory disease in pre-weaned calves, even more so than a reduction in airborne bacterial count (Lago et al., 2006).

Figure 2: The calf on the right has a nesting score of 3, as her hock and lower leg can't be seen in the long straw bedding.

In wintertime, use of calf coats on animals less than four weeks of age when evening temperatures are less than 10ºC can help improve gains by decreasing the amount of energy calves have to expend to stay warm. As calves get older and their rumen develops, they generate more body heat and their thermoneutral temperature drops to close to 0ºC. A calf coat or jacket is thought to be the equivalent of approximately one nesting score unit, so a calf with a bedding score of 2 with a jacket would be equivalent to a score 3 calf without a jacket (Van Os et al., 2021). Calves can overheat when daytime temperatures are high, so during fall and spring jackets should be removed during the day.

▪ Ventilation

For indoor housing, industry experts recommend barns with natural ventilation supplemented with positive-pressure tube ventilation (Nordlund and Halbach, 2019). The addition of positive-pressure ventilation allows fresh air to be brought in from outside without drafts during the winter, while in the summer, the positive-pressure ventilation supplements the natural ventilation, especially on still days.

Ideally, pre-weaned calves should be housed in their own airspace to decrease risk of disease. However, if calves are housed with older animals in a shared airspace, consideration must be given to how fresh air is brought into the barn so that it is delivered from the youngest to the oldest animals. Positive pressure tubes are custom designed for the building they are in and are designed to deliver fresh air to all areas of the barn, eliminating areas with dead space. They are also designed to avoid drafts, while still ensuring adequate air exchange, with the goal of delivering air to the calf level at a speed of less than 60 feet per minute, which is felt as still air (Nordlund and Halbach, 2019).

▪ Vaccination Strategies

Although vaccine programs can be of great utility, it's important to remember that even the best vaccine program will fail if there are holes in the colostrum management program, or if there are issues in the environment related to stocking density, air quality, bedding, etc. However, when these management areas are done well, they help a good vaccine program succeed. Animals experiencing stress such as crowding, mixing, dehydration, weaning, or limit-feeding have poorer immune function, which can impact their ability to respond to a vaccination (Chase and Villegas, 2016).

Determining which vaccines to give, and to who, depends on the specific risk factors and disease risks on an individual farm. Although general vaccine recommendations exist, it's best to work with your herd veterinarian to develop a strategy that will work for your farm.

There are vaccines available to improve antibody production to calfhood diseases in the cow, with the goal of producing colostrum with a high level of antibodies for specific diseases (typically scour-causing agents). While the label of these vaccines may recommend vaccination at three weeks pre-partum, it's clear that transport of antibodies from circulation to the mammary gland begins at three to four weeks prior to calving, peaking at one to two weeks pre-calving (Chase and Villegas, 2016). While non-adjuvanted vaccines are ideally given at four weeks pre-calving, adjuvanted vaccines generate higher antibody levels for longer periods of time, making them able to be successfully given earlier in the dry period (Chase and Villegas, 2016). Currently available scour vaccines in Canada are adjuvanted. When considering possible earlier calvings, and how often cows are vaccinated on a farm (e.g., weekly), it may make sense to target cows earlier in the dry period with scour vaccines than may be on the label to ensure adequate antibody production in colostrum. While there are specific antibody products available to supplement calves at birth, typically a well-managed dry cow vaccine program coupled with good colostrum management is preferred to an antibody supplement-based program.

While the antibodies that a calf receives in the colostrum are extremely important to ensuring good health in early life, they can interfere with the calf's response to systemic vaccines. Vaccines delivered parenterally (injected either under the skin or in the muscle) require a systemic response by the animal, which can be blocked by the presence of passively acquired antibodies from colostrum. However, intranasal vaccines avoid this issue by directly priming the mucosal immune system with little interference from these antibodies (Chase et al., 2008). As a result, intranasal vaccines for common respiratory pathogens have been a very successful strategy to generate protective immunity for several months (Chase et al., 2008).

Parenteral (injectable) vaccines offer a longer duration of immunity compared to intranasal but require a lack of maternal antibody interference and also require the animal to be healthy enough to respond well to the vaccine. Modified-live vaccines (MLV) are preferred to killed (inactivated) vaccines at establishing a good immune response, although there is also evidence that killed vaccines can effectively booster MLV vaccines (Chase and Villegas, 2016).

▪ Disbudding

Disbudding (removing the horn bud prior to attachment to the skull, which occurs at approximately two to three months of age) is preferred over dehorning because it is less invasive and less painful. Disbudding can be done by either hot-iron disbudding (cautery) or caustic paste (chemical disbudding); both methods are painful when done without adequate pain control (Stock et al., 2013). A large body of evidence shows that administering a local anesthetic (commonly lidocaine, given as a cornual nerve block, shown in Figure 3) and a non-steroidal anti-inflammatory drug (NSAID) effectively eliminates both the acute and inflammatory pain from cautery disbudding (Winder et al., 2018). While the nature, duration, and intensity of a chemical burn is different from a thermal, cautery burn, the use of both local anesthetic and NSAID analgesic is best practice for caustic paste disbudding as well (Stilwell et al., 2009; Winder et al., 2017; Reedman et al., 2019). While caustic paste, once applied, will take several minutes to start to cause a burn, it has been shown than an NSAID alone does not control the acute pain (Winder et al., 2017), whereas if lidocaine is also given, calves disbudded by caustic paste essentially show no differences in pain behaviour compared to those not experiencing disbudding (Winder et al., 2017). Figure 4 shows the differences in cortisol concentrations in calves disbudded with or without a local anesthetic.

Figure 3: A calf is administered a cornual nerve block. Local anesthetic (lidocaine) effectively mitigates the acute pain from disbudding but must be given in the correct location to be effective. Consult with your veterinarian for more information or training or see www.disbudding.com.

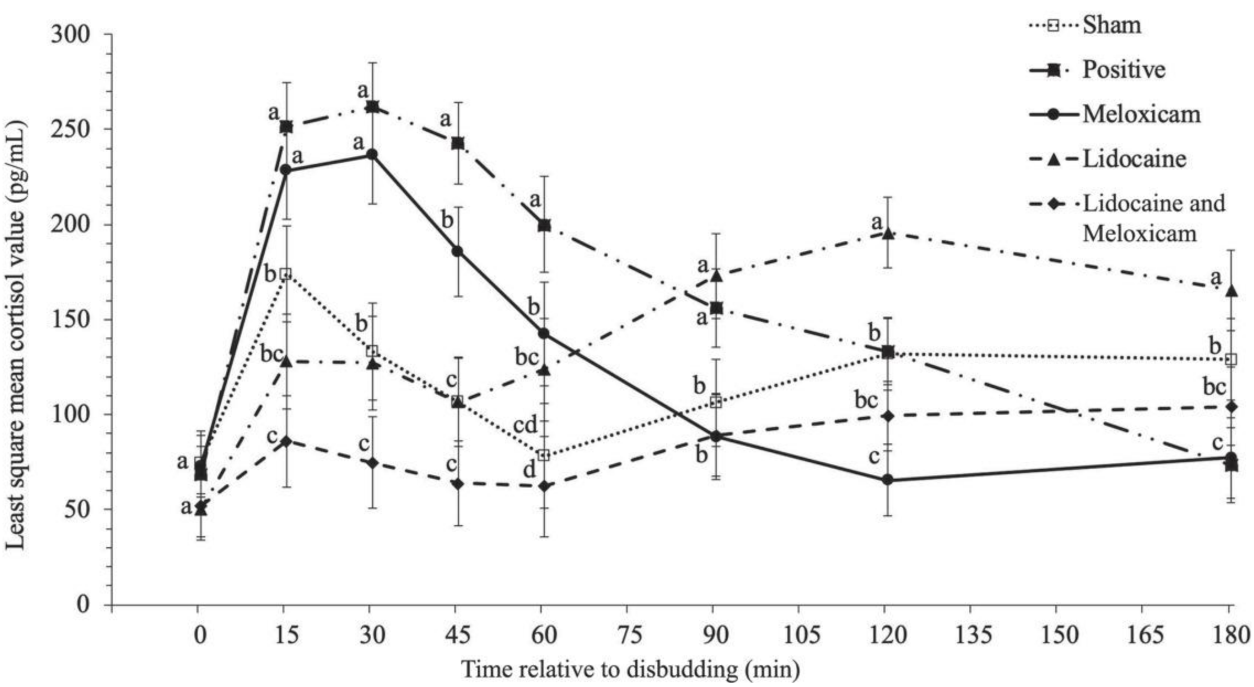

Figure 4: This graph displays the initial rise in cortisol for calves not given a local anesthetic (solid line with circles and dotted and dashed line with squares), which is mitigated for calves receiving lidocaine (dotted and dashed line with triangles, dashed line with diamonds). However, at approximately 60 to 90 minutes following caustic paste application, the inflammatory pain begins to rise in calves not given an NSAID in addition to the local anesthetic (dotted and dashed line with triangles), while calves given both lidocaine and an NSAID (dashed line with diamonds) remain low for the entire study period. The same results have been seen for pain behaviours such as head shaking, ear flicking, and head rubbing.

While it is recommended to disbud calves with enough time for them to heal before weaning, there has been little work exploring age at disbudding. In fact, a preliminary study suggests that calves disbudded at three days of age may show a generalized long-term increase in pain sensitivity compared with calves disbudded at 35 days of age (Adcock and Tucker, 2018). It is also important to avoid time periods of additional stress in calves, which may be different for different farms; working with your veterinarian can help you determine what age calves are best disbudded on your operation.

Sedation, typically xylazine, may be used to aid in handling. This drug provides conscious sedation and is not appropriate to be given alone for pain control for disbudding (Grondahl-Nielson et al., 1999; Stilwell et al., 2010). The impact of sedative on the stress of the procedure is unknown; while several recent studies have explored this topic (Cuttance et al., 2019; Reedman et al., 2021) results have been mixed.

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Wellbeing and Productive Farming

Cynthia Beck

MSc Clinical Psychology; Co-director, SaskAgMatters Network
Email: cynthiabeck@sasktel.net

Take Home Messages

- YOU are a major asset to your operation.
- The ability to be an asset is impacted by your wellbeing, which includes physical and mental health.
- Cattle cannot feed themselves and the tractor cannot fuel itself; make self-maintenance a priority by fuelling and hydrating your body to help sustain productivity.
- Negatively impacted wellbeing increases risk of farm injury and rates of illness and decreases decision-making ability and productivity.
- Visible warning signs of decreasing producer health include farm and animal health deterioration.
- Simple self-maintenance, which includes getting some sleep, drinking water, and eating throughout the day, helps to improve and maintain wellbeing.

Introduction

A theme I often run into while speaking on the importance of mental health in agriculture is producers (male and female) who dismiss the topic and ask, “What does mental health have to do with farming?” My response is always the same, “How do you feel about having the money to pay your bills?”

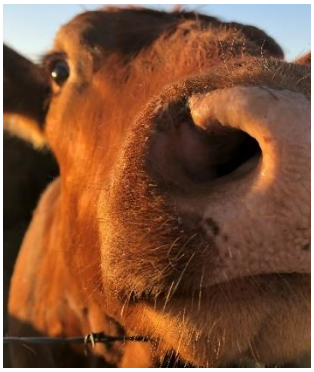
Your wellbeing affects your productivity, which affects your bottom line. As an agriculture producer myself, I know how much that bottom line matters. As a researcher, a rural mental healthcare provider, and a suicide intervention responder, I know the extent to which wellbeing impacts one’s ability to function physically, mentally, and emotionally.

Perhaps producers walk away from or avoid talking about mental health and wellbeing because, up until recently, it was not commonly talked about. As a population, we are well versed at talking about the weather, input costs, the expense of machinery and feed, and livestock genetics. All those things are part of our cultural language. For many of us, we grew up listening to our parents or neighbours speaking about agriculture, which one could argue is quite similar to learning a first language — of course we are comfortable speaking about agriculture related topics. However, what are the chances you heard conversations about health and wellbeing during your childhood or young adulthood? Did you ever hear your parents or neighbours conversing about health, aside from “Did you hear the neighbour broke their leg” or “So and so had a heart attack”?

Another theme I occasionally observe at agricultural events is producers making a quick exit as mental health related presentations are introduced. Perhaps producers walk away because they have previous exposure to ineffective and possibly harmful talks about mental health. I have heard a variety of mental health presentations that ranged from boring as hell, had nothing to do with agriculture, were incredibly triggering without de-escalation, or made me feel worse about myself rather than better. No fun! Those presentations — where we are inadvertently made to feel worse — are not fun, so why would people willingly expose themselves to that further?! Believe me, I get it; we have enough on our plate.

Perhaps a primary reason behind producers walking away from health-related topics is attributable to avoidance. They may not be in the space to hear it, for example, "I can't deal with this right now." Some producers may not be in a place to take on additional workload, and let's be real, working on oneself does require a little time and energy. During high production seasons on the farm, calving for example, I am very hesitant to take on additional projects or tasks because of lack of time and energy and other life commitments. My thesis research supports this idea, given that every producer reported waiting for down time before participating in an online therapy program for agriculture producers (Beck, 2022; www.onlinetherapyuser.ca). Other researchers have found that individual producers may not be ready or willing to take a good look at themselves because they report managing fine on their own, they have concerns about making their situation worse, they have no idea how to go about getting help, or they are concerned about stigma (Gregoire, 2002; Canadian Agricultural Safety Association, 2005; Hagen et al., 2021).

In my opinion, the players in the agriculture industry have come a long way in promoting mental health awareness. Different levels of government are advocating for agricultural mental health, through Committee hearings on a federal level (Finnigan, 2019) to mental health presentations hosted by provincial and municipal governments. National agricultural associations and events are creating opportunities for mental health conversations, as are provincial livestock and breed associations. Universities, researchers, and funding agencies are dedicating major resources to agricultural mental health research, advocacy, and outcomes. To list all of the agencies, associations, institutions, and individuals actively trying to make a difference in agricultural mental health, the list would take pages, and for that I am immensely grateful.



Here is the kicker in all of this though: we can research, advocate, throw money at, and talk about mental health until the cows come home, but it is up to you, the individual, to choose to have an open mind and hopefully gain some awareness of your state of health and wellbeing, and then look at the impact you have on your farm operation or business. My goal in these proceedings is to be real with you as to what health and wellbeing mean as an agriculture producer, to provide the warning signs of decreasing health, and to provide you with doable strategies for improving overall health, wellbeing, and productivity. Please be forewarned, my light-hearted and straight forward approach and expressive language use in conversing about mental health may be surprising to some viewers.

▪ What is Wellbeing?

The Oxford English Dictionary defines wellbeing as "the state of being well or doing well in life; happy, healthy, or prosperous condition; moral or physical welfare (of a person or community)." This definition applies well to the agriculture population. We are a large community; we care about the welfare of our family, friends, community, and employees; we work long and hard to be prosperous (fingers crossed!); and when farming is going right, we are bound to feel a sense of pride and joy.

From a producer and mental health care provider point of view, the above definition requires some 'beefing up' to meet the needs of an agriculture producer's lifestyle. Wellbeing as it applies to producers also means that we have the ability to live where we work and work where we live.

Think about that for a moment — in what other industry do you work with a co-worker who possibly frustrates the hell out of you or argues with you all day long, and then you go to bed with them at night or sit down to a full family holiday meal with them?

There are days when it is not easy, especially in the case of multigenerational farming operations. Wellbeing includes having the ability to care for our livestock regardless of how tired we are or how cold it is outside and having the ability to forward think, to problem solve, and to communicate effectively. For example, we need to know long before the snow arrives whether or not we have enough feed and bedding for our herd to get us through winter.

Just to be clear, wellbeing is not an all or nothing type of thing, which is the same for our physical and mental health. It moves along a continuum. Each person has different levels of healthy as much as we have different levels of unhealthy. We can think of it similar to that of cows' milk production. Each of your cows produces an average amount of milk daily, some naturally produce more or less than others. They each have their 'normal'. All of your cows contribute to you meeting your quota; therefore, they are assets to your farm operation. One day you notice that Holly 102C's ears are droopy and her milk production has been down the last couple of days. She has mastitis in one quarter. So, you treat her and keep milking her, but the milk cannot go into your tank. She is currently at a different level of healthy. She is still an asset to your operation but less of an asset when it comes to helping you meet quota. With a little care and additional maintenance, Holly makes a full recovery, and she is back to contributing productively to your operation. If you were to ignore poor Holly's mastitis, what would happen? Her health would deteriorate further, she would stop producing milk and start costing you money due to her lack of productivity and cost to feed. A cow's health can fluctuate, and when her health fluctuates so does her productivity. Humans are the same.

▪ Are You an Asset?

If you had a heart attack tonight, would your farm operation continue running as is tomorrow? Despite the wonders of automation, cows cannot feed themselves, feed doesn't magically harvest itself, and machinery cannot pump its own fuel. You are the number one asset to your operation, and so are the people who work with you.

Have you ever taken a moment to think about the many roles that you and the people whom you farm with fulfill? The work does not get done without the people power, and keep in mind, just like our cows, there are times when we humans are less of an asset. Take a look at the list below (Figure 1); have you ever thought about the roles you play in your operation, or the amount of knowledge you use on a daily basis?

- Mechanic to maintain or fix machinery
- Agronomist to plan crop rotations, pest and weed control
- Business manager to budget and plan years in advance
- Accountant to balance books and deal with government regulations
- Marketing and salesperson to sell one's products
- Veterinarian / nutritionist / doctor to maintain animal/people health
- Genomics expert to select and manage livestock bloodlines
- Therapist to maintain farm family relationships
- Care provider / crew chef / parts picker upper / vehicle mover
- Labourer who does an endless amount of manual work

Figure 1: The roles of farmers in their operations.

▪ What Affects Wellbeing?

If you were to go fencing for the day, would you just hop in your truck or tractor and drive off without fueling up or loading fence posts, wire, staples, or even a hammer? Probably not (if you responded ‘yes’, we need to chat), because it would be a total waste of your time. You wouldn’t get any work done.

We do maintenance on our equipment or machinery on a regular basis: fuel, grease, tires, oil. Most of the producers I know plan ahead to make sure they have the supplies they need to do a good day’s work, which is called being proactive. The skill of being proactive in farming helps to increase our work efficiency, which also increases our productivity.

How often do you head out for the day without fueling yourself? Many people leave for work for the day with just a cup of coffee in their belly (guilty) and running on little sleep (yup, guilty of this too). One could say it is common sense and good farming practice to maintain machinery and be proactive yet it is quite common that we forget to do our own self-maintenance.

Self-Maintenance

Self-maintenance is the term I prefer to use instead of saying ‘self-care’. I’ve heard many people in agriculture voice that self-care is frivolous or even selfish, that it has to include a holiday, warm bubble bath, a spa day, or a weekend getaway. As agriculture producers, trying to meet those expectations of ‘self-care’ is unrealistic and sets us up for failure.

Basic self-maintenance has more of a long term impact on our health and wellbeing than does a one-time holiday. Self-maintenance includes getting adequate sleep, drinking water to hydrate your brain and body, balanced nutrition to fuel yourself, moving your body, disconnecting from the workload and the stress, and adding positive activities into your life that are separate from your farm or business.

Diminished Self-Maintenance

For many agriculture producers, our health and wellbeing takes last place on the priority list of things to do. During high production seasons, we work incredibly long hours and perhaps deprive ourselves of sleep. I know some producers who work for the day without taking breaks, and they eat one meal per day, basically when they come in at night.

If we were to avoid doing basic maintenance on our machinery, like fueling up or tire maintenance, that machinery would leave us stranded and cost us in productivity. Our body is very similar; if we are not sleeping, eating, or hydrating, our body has to work harder to be productive, similar to the tractor in the picture with the tire that fell off (Figure 2). A little maintenance and this tractor will be back doing its job. The combine on fire, however, may be a different story.

Figure 2: Your body, like your machinery, needs to be properly maintained to be productive.

There are times when we push ourselves too hard for too long. If there is a lot of work and as many problems, we tend to do put our noses to the ground and work harder. Perhaps we go without sleep and reach for caffeine, energy drinks, or drugs to keep on going. Perhaps we put off eating or we reach for convenience foods that provide little fuel to sustain our body. It is typically during these same times that stress can be overwhelming.

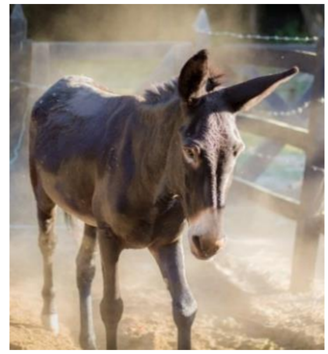
Everyone deals with stress differently. Some people try to cope by working harder. Some people try to cope by using substances like alcohol or recreational drugs. Some people cope by inadvertently lashing out at the people around them. In our family, we call this 'shit-flinging' or manure spreading, when someone who is having a bad day unleashes the emotions, anger, and frustration out onto those around them – the people who are typically trying to help solve the problem.

These ways of coping — not sleeping, not eating, not drinking water, or relying on caffeine, drugs, alcohol, and allowing the stress to impact those around us — all negatively impact our wellbeing and the wellbeing of our family and co-workers (Fraser et al., 2005; Yazd et al., 2019).

Contextual Factors

Contextual factors are characteristics within our environment that influence our behaviour. Nearly every aspect of an agriculture producer's life is inextricably linked with their work life, which has mental health implications for producers and their family members. Many producers live on their farm and have little to no separation between their workday and their personal life (Fraser et al., 2005; Yazd et al., 2019).

Producers take little to no personal time and are less likely to retire than people in other occupations (Gregoire, 2002; Brew et al., 2016; Fullerton, 2016). Working with family on the farm also poses a challenge for separating work life from personal time and has been identified as a key stressor for Canadian producers (Sturgeon and Morrissett, 2010; Finnigan, 2019). In 2016, 97% of farms in Canada were family farm operations (Statistics Canada, 2016), with some Canadian farms having up to four generations actively working on or involved in farm decision making (Fullerton, 2016). Conflicts and relationship strain often arise when the oldest generation and the adult siblings are partners in a family farm, and all hold differing



priorities for farm growth and expenditures or have differing beliefs regarding work ethic and work hours (Fraser et al., 2005; Rudolphi et al., 2020).

During seasons of high productivity, producers are under pressure to accomplish a large amount of work within a short period of time (LaBrash et al., 2008; Lilley et al., 2012). Long work hours equate to diminished sleep hours, and periods of high productivity are often accompanied by increased stressors and worries.

Producers report experiencing daily worries and sleeplessness regarding debt and cash flow, which contribute to impaired sleep quality (LaBrash et al., 2008). Fatigue impairs cognitive functions such as multi-tasking, attention and awareness, decision making, and risk taking (Lilley et al, 2012). Research findings further highlight that diminished sleep duration and poor sleep quality are associated with increased rates of anxiety and depression (Hawes et al., 2019; LaBrash et al., 2008).

Occupational Hazards

In addition to the self-maintenance and contextual factors, our wellbeing, physical and mental health can be impacted by occupational hazards. Simply by the nature of the lifestyle we lead in the agriculture industry, producers are exposed to potential injury from:

- mechanical forces or equipment (please turn off the P.T.O, watch out for the grapple)
- livestock
- needle, medication, or vaccination exposure
- environmental exposure (we look after the herd in all kinds of weather)
- chemical exposure (anti-parasitics, pesticides, herbicides)
- biological exposure (rodent feces, dust, mold)

(Gregoire, 2002; Brew et al., 2016; Donham and Thelin, 2016).

The Impacts of Challenged Wellbeing

Signs of Decreasing Mental Health

Anxiety is our body’s natural response to stress and people experience it differently. For some, anxiety may feel like an upset stomach and for others it may feel like a heart attack.

Low mood or feeling down is a natural response to upsetting or sad events in our daily life. It is also normal to experience periods of low mood or worry, which are natural reactions to dealing with constant stress.

If you find yourself feeling down or hopeless more often than not, you may be dealing with depression. Men, women, and children experience depression differently. Psychiatric symptoms can occur when a person is experiencing challenges to their mental health (Canadian Mental Health Association; https://cmha.ca/).

There are people who have experienced health and wellbeing difficulties for such a long time that it has become their ‘normal’ state of being. I’m sure you can think of someone (e.g., friend, neighbour, family member) who is a total jackass, and no one likes to deal with them.

Are they a jackass because that's who they are, and it is part of their personality or are they a person experiencing long term, unchecked mental health and wellbeing difficulties?

Quite often it is easier for us to spot the warning signs of decreasing mental health in others more so than in ourselves. Many warning signs are outwardly visible (Figure 3).

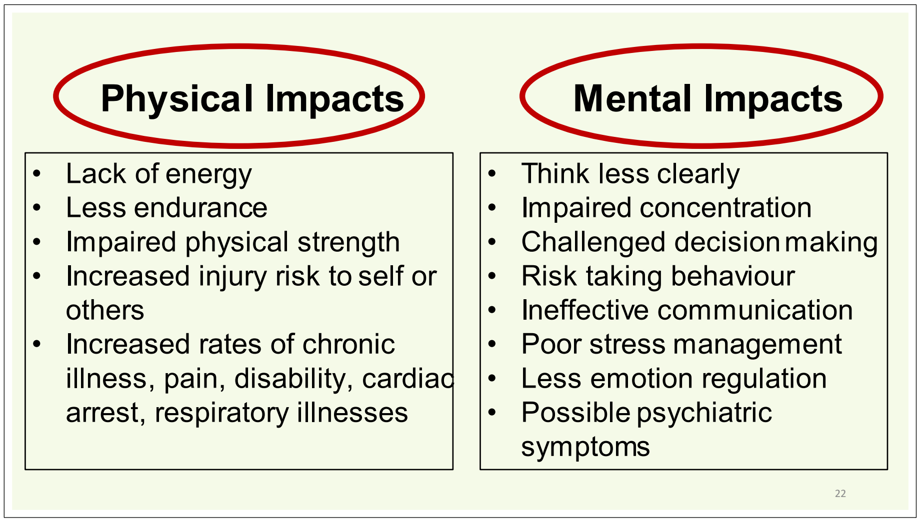


Figure 3: Warning signs of challenged wellbeing.

Here are a few warning signs that you may recognize experiencing yourself or that you recognize from observing others:

Changes to routine: sleep, hygiene, diet, substance use

- For people experiencing psychiatric symptoms, they may be sleeping odd hours of the day, requiring more sleep than usual, or having difficulty sleeping and waking because thoughts keep turning over in their mind (called rumination).
- If you know someone who was always clean shaven and well-kept and then you see them in town with dirty clothes, straggly hair and unshaven, they may be experiencing challenges to their mental health.
- Changes to diet can occur in either direction: a person may find it difficult to eat and experience weight loss, or a person who may normally be a healthy, mindful eater may reach for convenience or comfort foods and binge eat.
- If you know someone who was a social drinker and you see them with alcohol in the cab of the tractor in the morning, they may be experiencing challenged mental health.
- Some people experiencing difficulties will try to self-medicate in order to cope by taking recreational drugs, increasing alcohol intake, or taking prescription medications not as prescribed.

Changes to energy levels

- If you know someone who has always been fairly even keeled and suddenly they have periods where they are very high energy or very low energy, they may be experiencing challenged mental health.
- Decreases in motivation and difficulty finding the determination and energy to get the work done can be psychiatric symptoms.

Emotions are off

- Sometimes people describe themselves as feeling numb, like their emotions are turned off.
- People may have emotional reactions that don’t seem to fit the situation (e.g., laughing at a funeral).
- Difficulties with emotion regulation may be signs of challenged mental health (e.g., yelling over insignificant things, uncontrollable crying).

Difficulty concentrating or with memory recall

Withdraw, isolate, or stop communicating with others

Engage in risky behaviour

- This may include using substances and operating machinery or engaging in unsafe farm practices

Uncharacteristic judgment or decision-making

- Suddenly making a large purchase (e.g., buying a second combine during a drought) or snap business decisions with long term implications (e.g., deciding to sell the cowherd during the night and the cattle liner loads in the morning)

Deterioration of farm or animal health

Tips for Improving Wellbeing

Do the self-maintenance! Do the self-maintenance! Do the self-maintenance!

Make yourself a priority, even if it is for ten minutes in the morning for you to drink a glass of water, eat breakfast, and fill a water bottle and grab snacks to fuel yourself for the day. As agriculture producers, we may not be able to control some factors that contribute to challenged health and wellbeing, like the weather or government regulations. However, in our first world country, we do have control over whether or not we drink a glass of water in the morning and eat something.

Please get some sleep. Yes, there are times in the farming year, calving for example, when getting adequate sleep is difficult. During high production seasons, it is imperative that we nap when we can. No one wins a medal for running on empty, and fatigue can be dangerous and costly. Try to eat meals during the day and not wait to eat one big meal at the end of the day, which makes it more difficult for your body to sleep.

There may be times when agriculture producers are quite sedentary due to operating machinery. Moving your body, even by walking to the barn instead of taking the truck or quad, is beneficial to get the blood flowing and the heart rate elevated.

Work on learning how to disconnect from the workload and disengage from the stress. These are important skills to learn. For many agriculture producers, their entire world is the farm operation. It is difficult to maintain a balanced perspective when one’s entire purview consists of the farm.

Think of it as a mountain; if one is standing right at the base of the mountain, which is the cliff face, then one’s entire field of vision is filled with an insurmountable problem; it is impossible to see a solution. Drive a little way away from that cliff face (the problem), and you may gain an entirely new perspective which allows you to find solutions.

Another reason for disconnecting from the workload and the stress is to create opportunity for adding more to your self-identity than the farm. One of many reasons why the potential of losing the farm or retiring is so stressful is because producers are left wondering, “Who am I now?”

I’m sorry to be the person dropping this truth bomb on you, but one day we all retire from farming, whether it be to go enjoy life or it be in a body bag, but you will retire. Adding positive activities to your life now, that are separate from your farm or business, are beneficial to your health and wellbeing. Those positive activities allow you to explore and grow as a person, to develop a well-rounded self-identity, to disconnect from the work and stress, and who knows, you may even enjoy yourself!

Communicate with your family or business partners and make a plan in the event of illness. Hopefully you can also talk about and develop a business plan. Research findings have identified that having a business plan and plans in place in event of illness reduces stress for all business partners (Wilton Consulting Group, 2020).

Learn your triggers and patterns of coping. Many people experience cyclical mental health challenges. For example, people may find their mental health automatically deteriorates in the winter and then improves in the spring or summer.

While volunteering as a suicide intervention responder, it became very apparent to me that people experience increased challenges to their mental health and wellbeing during certain periods of the farming year. For example, some people’s mental health and wellbeing deteriorates during calving season year after year, which makes sense because the calving season comes with increased workload, increased stress load, and decreased sleep quality and quantity.

For other people, it may not be the time of year that triggers mental health challenges, it may be something else, for example, farming with family. If you can start paying attention to how you are doing and learn to recognize what upsets you or causes you frustration, then you can possibly prepare ahead of time and develop some coping strategies. Some producers have told me that just knowing they’ll probably experience mental health challenges during a certain period of time helped them to maintain perspective and to know that it would not last forever, which helped them to get through it.

Please recognize the stress you choose to add. Do you have a to-do list that has unchecked items on it from a month or years ago? These perpetual lists that rarely get accomplished do very little aside from making you feel worse about yourself. Instead, create a ta-da list; the only items that are placed on this list are items that can realistically be done in the morning. Then at lunch, you cross off the tasks you finished and create yourself a new list. Be realistic with your expectations and set yourself up for success.

Additionally, are you taking on stress that may not even belong to you? There are times when we inadvertently create challenges for our health and wellbeing by comparing ourselves, our accomplishments, and our life to that of our neighbours. I call this toxic comparison.

If you find yourself wondering why the neighbours can afford that shiny new tractor or a house at the lake and you can’t, or how they can manage taking vacations and you can’t, how is this helpful to you? It’s not helpful, and in fact, it has the potential to be very harmful to your state of health and wellbeing. It wastes your time and energy. Toxic comparison can be lethal. No two farming situations are alike, and we have no idea what happens behind someone else’s closed doors. Keep in mind, the stuff people choose to share, whether it be in person or on social media, is the glossy parts of their life and is rarely a reflection of their true reality.

Mind your own business and manage your own stress instead of adding the stress from toxic comparison. The only time it is fruitful for you to mind other people’s business is if you would like to learn new management practices or new skills from them for your own growth and development.

The last thing I encourage you to do is learn, for your own health and wellbeing, how to accept help. As agriculture producers, we have a lot on our plate. We deal with prolonged periods of stress, we push our bodies to the limit, and most producers try to carry the burden on their own. Learning how to accept help is an acquired skill.

If by now you have recognized that you are experiencing challenged mental health, please be proactive and take steps to do something about it. There is help available (see resources below). Please talk to a trusted person or a professional. Many producers report having concerns with experiencing stigma if they go get help for their mental health. Speaking as a producer and a mental health care provider, the biggest stigma that we deal with is the stigma we place on ourselves with the talk in our own head.

If you have a sick cow, do you give her medication to nurse her back to health or do you prefer to watch her slowly deteriorate, struggle, suffer, and die? That may seem like a ridiculous question. Yet for many of us, that's what we do to ourselves instead of taking the steps to get some help. You are worth it. Please remember, you and the people you work with are the number one asset on your farm operation.

▪ Resources:

Canada-Wide Services and Resources:

The Government of Canada, the United Way, and provincial partners have teamed up to fund 211, which is available in every Canadian province and territory. Similar to 911, which is for emergencies, 211 is for mental health and wellbeing supports.

You can call or text to 211, literally all you need to dial is 211, and a worker will help you to identify the support you need and help you to find supports in an area near you.

There is great information on each provincial website. https://bc211.ca; https://ab.211.ca; https://sk.211.ca; https://mb.211.ca/

Online Therapy Unit: https://www.onlinetherapyuser.ca/

Canadian Mental Health Association: https://cmha.ca/

The Canada Suicide Prevention Service Call: 1-833-456-4566 (Available 24/7/365); Text: 45645 (Available 4pm - midnight ET); https://www.crisisservicescanada.ca

Agricultural Health and Safety Network: https://cchsa-ccssma.usask.ca/aghealth

Do More Agriculture Foundation: www.domore.ag

Centre for Addition and Mental Health: www.camh.ca

National Farmers Union: https://www.nfu.ca/help/

Farm Credit Canada: https://www.fcc-fac.ca/en/community/wellness.html

British Columbia Resources:

The B.C. Ministry of Agriculture, Food and Fisheries provide numerous resources in the following pdf: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/business-and-market-development/emergency-preparedness/flood-2021/mental_health_resources_for_agriculture_sector.pdf

Alberta Resources:

Agricultural Service Boards: https://agriculturalserviceboards.com

Alberta Farm Mental Health Network: https://www.agknow.ca/

Alberta Mental Health & Suicide Prevention Resources: https://www.farms.com (this website lists many mental health services in AB)

Centre for Suicide Prevention : https://www.suicideinfo.ca/resource/

CORE Alberta: https://corealberta.ca/resources/mental-health-resources-farmers

Saskatchewan Resources:

Saskatchewan Farm Stress Line: www.farmstressline.ca; 1-800-667-4442

SaskAgMatters Network: www.saskagmatters.ca

Online Therapy Unit: www.onlinetherapyuser.ca

Manitoba Resources:

Manitoba Farm Stress Line: https://supportline.ca/

Call toll free: 1-866-367-3276; https://www.tmsd.mb.ca

Manitoba Farmer Wellness Program: https://manitobafarmerwellness.ca/

Shared Health Manitoba: https://sharedhealthmb.ca

Klinic Community Health: https://klinic.mb.ca/2018/01/mental-health-farm/

Ontario Resources:

Agriculture Wellness Ontario: https://AgricultureWellnessOntario.ca; 1-866-267-6255

Ontario Mental Health Line: www.connexontarios.ca; 1-866-531-2600

The Farmers/ Toolbox: www.thefarmerstoolbox.com

Quebec Resources:

Au Coeur des familles agricoles : https://acfareseaux.qc.ca/

Suicide Prevention Centre of Quebec : https://www.cpsquebec.ca/en/formations-population/

1-866-277-3553 (bilingual)

Prince Edward Island Resources:

Farmers Talk: www.farmerstalk.ca; 1-800-218-2885

EACH OTHER: a great resource that we often overlook is our fellow agriculture producers

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Minimizing Stress to Enhance Cow Health and Productivity

Meagan T. M. King[1] and T. J. DeVries[2]

[1]Department of Animal Science, University of Manitoba, [2]Department of Animal Biosciences, University of Guelph
Email: Meagan.King@umanitoba.ca

Take Home Messages

- Management, housing, and handling of animals should consider cows' behaviour, their physical environment, and their social environment to reduce physiological, psychological, and social stress and enhance their health, welfare, and productivity.
- Little things add up (or potentially even multiply!). Even small stressors and moderate/subclinical diseases can negatively impact cow behaviour and production.
- Don't forget to take care of yourself! So many farmers put their animals first and it is crucial to take care of your own physical and mental health as it will benefit everyone around you, including your animals. Also, remember there are other factors that contribute to your well-being besides just health.

Introduction

Managing the stress of dairy cattle has vast implications for animal health and productivity. While the combination of good management, housing, and handling can enhance animal health and optimize production and efficiency, shortcomings in any of those aspects can cause stress. Temple Grandin uses this definition of stress: it is "a condition in an animal that results from the action of one or more stressors that may be of either external or internal origin; whether a stressor can be considered as harmful depends on the way an organism is able to cope with a threatening situation" (Temple Grandin citing van Borell, 2001). Stressors can have both physiological and psychological effects on animals, which can lead to changes in cow behaviour and health status, negatively impacting cow welfare, production, and reproduction (Figure 1).

Various aspects of management, housing, and handling can cause stress related to cows' physical environment and comfort, as well as their social environment. Management considerations to reduce animal stress include animal grouping and regrouping, feeding, and dry off management. Animal housing impacts health and productivity includes comfort of lying spaces, stocking densities, and heat stress abatement. Handling methods that work with cows' natural behaviour can reduce stress, labour, and injuries to animals and handlers. A lot of research has demonstrated the negative consequences of different stressors in isolation, but in commercial farms, there may be interacting effects between multiple stressors. Therefore, multiple stressors may add up or they may even interact in a synergistic but negative way.

Health disorders can also cause stress and behavioural changes that have negative effects on cow productivity. Even cows with moderate lameness and subclinical ketosis exhibit changes in behaviour and production (King et al., 2017, 2018). In the 2016 National Dairy Study, which surveyed Canadian dairy stakeholders (where 68% of respondents were farmers), animal welfare was identified as the top-ranking management priority and lameness was the top disease priority (Bauman et al., 2016). But despite cow health and welfare being a priority for the industry, the true prevalence of disease is often underestimated if we focus our efforts on severe cases, even though subclinical cases are much more prevalent. Although farmers are aware of these issues and consider lameness and mastitis to be painful, farmers and even their veterinarians often underestimate the number of lame cows. Thus, these disorders remain prevalent on Canadian dairy farms, negatively impacting cow health, welfare, and productivity.

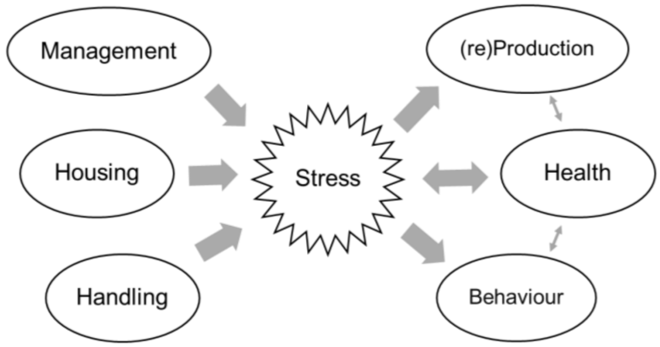

Figure 1. Flowchart to visualize the interconnections between some key factors associated with stress in dairy cattle.

Finally, with so much attention placed on animal welfare, the perspective of farmers is often overlooked, even though they are the ones providing care to animals daily, having the greatest impact on animal welfare (Kauppinen et al. 2010). There is growing evidence that the health and welfare of dairy cows are related to the well-being of dairy farmers (Hansen and Østerås, 2019; King et al., 2021). This connection aligns with the 'One Welfare' approach, related to 'One Health'. The One Welfare framework "describes the interrelationships between animal welfare, human well-being, and the physical and social environment" (Pinillos, 2018). Therefore, when considering ways to reduce stress for dairy animals, it is crucial to remember that the best way to improve animal welfare may be to also focus on improving the well-being of the farmer.

▪ Management and Stress

Grouping & Regrouping

Group composition can be optimized and maintained to minimize the psycho-social stress experienced by dairy animals. For pregnant first-half heifers and first lactation cows, being housed with older cows can impact their behaviour, resulting in lower lying times (Kaufman et al., 2016), eating times, dry matter intake (DMI), and milk yield (Bach et al., 2006) and they need more ketosis treatments after calving (Østergaard et al., 2010). Housing first-lactation cows with older animals can also interact with high stocking densities, as shown by greater fecal cortisol concentrations, indicating that first-lactation cows may have difficulties adapting to competition (Huzzey et al., 2012).

Regrouping cows with other cows or into a new group can also be a stressful event; it takes up to 24 to 72 hours for cows to re-establish their social hierarchy (Moran and Doyle, 2015). This is especially stressful on cows in their first lactation just after calving. Regrouping events negatively affect behaviours such as lying, ruminating, and feeding. Regrouping events can further increase agonistic behaviour between cows and impact milk production (von Keyserlingk et al., 2008; Schirmann et al., 2011). Because regrouping cows frequently before calving may constantly introduce new competitive interactions, cows should not be regrouped more than once per week. Other recommendations to reduce regrouping stress include limiting stocking density in those pens, introducing new animals in pairs instead of alone (especially when grouping heifers with older cows), or even better, creating stable 'all-in-all-out' pens when possible.

Feed Management

How, when, and what cows consume has huge implications for cow health and productivity. Improper feed management can cause physiological stress and can be compounded by social stress. In terms of the physiological impacts of feed management, there are effects not only on ruminal health, but also on udder health, hoof health, and productivity.

Changes in diet can impair rumen function by disrupting gut microbiota and decreasing feed intake. This is especially stressful during the transition period and at dry off, where cows are already undergoing considerable physiological and psychological stress. Ruminal stability is best supported by small, frequent meals consumed slowly, with minimal feed sorting. Increasing the number of meals a cow eats in a day can also improve her fat-correct milk yield. Further, increasing the frequency of fresh feed delivery and feed pushups can improve access to feed, reduce feed sorting, and decrease the displacement of subordinate cows from the bunk, increasing milk yield at a herd level.

Udder health may be improved by encouraging cows to eat after milking to allow teat canals to close before cows lie down.

Finally, hoof health can be impacted by access to feed. Herds with barriers creating separate feeding spaces had a lower lameness prevalence compared with those with a post-and-rail (Sarjokari et al., 2013). Lameness was also less prevalent in herds with wider feed alleys (Sarjokari et al., 2013; Westin et al., 2016) and more feed bunk space (Matson et al. 2022). Therefore, continual access to feed throughout the day with limited competition is essential for healthy feeding behaviour.

Dry Off Management

Late-lactation cows can experience a significant amount of physiological stress when dried off abruptly, as indicated by high intramammary pressure and cortisol concentrations in the blood and feces (Bertulat et al., 2013). This is especially important for high-producing cows (producing > 20 kg/d) and may not be necessary for lower-producing cows (producing < 15 kg/d). Skipping milkings or reducing milking frequency reduces milk yield before dry off and milk leakage after dry off, but this does not always translate to a reduced risk of intramammary infection (IMI) after dry off (Gott et al., 2016).

Although study results have varied, there is a general consensus that the target milk yield at dry off should be 15 kg/d or less to improve udder health. First-lactation cows exhibiting milk leakage and those dried off abruptly had a higher risk of IMI, whereas multiparous cows were more likely to have IMI with gradual milking cessation (Gott et al., 2016). Furthermore, primiparous cows' lying time is often more sensitive than that of multiparous cows relative to their milk yield at dry off or in response to abrupt dry off. Therefore, there may be differences in optimal dry-off strategies for cows based on parity.

▪ Housing and Stress

Rest Areas

In all barn types, cows need to rest on clean and dry bedding, maintained at an adequate depth; otherwise, cows will stand excessively or perch in their stalls, leading to the development of hoof lesions and lameness. The increased time spent standing in slurry can increase the risk of developing soft tissue lesions, and inadequate rest time can reduce blood supply to the hooves and the ability to heal. Unfortunately, subordinate cows also spend less time lying down and more time standing and perching, which increases their risk of soft tissue lesions and lameness (Galindo and Broom, 2000). It is also beneficial to separate sick and lame cows and provide them with more comfortable bedding (e.g., bedding pack) and easy access to the milking area.

Type of bedding: Sand bedding has become the well-known 'gold standard' choice of bedding to support udder and hoof health. Relative to non-sand surfaces and mattresses, sand bedding has been associated with 10%-point reductions in lameness prevalence (so 20% of a herd instead of 30%) and greater milk production (reviewed by Bicalho and Oikonomou, 2013). Lame cows are also better able to perform natural lying behaviour in deep-bedded sand stalls.

Quantity of bedding: Cows prefer and will spend more time lying down on deep-bedded stalls (either sand or sawdust) compared with mattresses. Each extra kilo of bedding per stall can increase cows' lying time significantly (Tucker et al., 2009). At the bare minimum, bedding should be at least 2.0–2.5 cm deep to reduce lameness and knee injuries; increasing bedding depth above 7.6 cm further reduce levels of lameness, dirty udders, dirty flanks, and hock injuries.

Quality of bedding: The management of bedding is just as important in achieving a comfortable rest area for cows. In Canadian tie stall herds, wet bedding was associated with higher odds of lameness (Jewell et al. 2019).

Stall size: In freestall herds, obstructed lunge space and not fitting the width of lying stalls was associated with lameness (Westin et al., 2016). Higher curbs at the back of stalls have also been associated with greater lameness prevalence (King et al., 2016; Matson et al., 2022).

Stocking Density

Overcrowding cows can lead to limited access to rest areas, feeding space, water, and other valued resources. This can create stress both physiologically and psychologically because cows must compete for limited resources. Aggression and competitive displacements can impair healthy feeding behaviour and result in higher fecal cortisol levels, indicating higher activity or stress (Proudfoot et al., 2018). Overstocking cows can also impair immune function and increase the risk of subclinical ketosis in fresh cows. Higher stocking densities have also been related to greater lameness prevalence and lower milk yield in both robotic and conventional freestall herds, whether it is the number of cows relative to lying stalls (King et al. 2016; Westin et al. 2016) or feed bunk space (Matson et al. 2022). In herds with robotic milking systems, the number of cows per robot negatively affects milking frequency, showing the importance of all aspects of stocking density (King et al., 2016).

Heat Stress

Heat stress is an obvious physiological stressor for dairy cows, as it can cause immune suppression and may contribute to systemic inflammation. Whether exposure to heat stress is during lactation, the dry period, or gestation, heat stress impairs the health, fertility, feed intake, and milk production of cows and the immunity and growth rates of calves. Furthermore, the daughters and even granddaughters of pregnant cows exposed to heat stress show lower milk production and a lower probability of survival (Laporta et al., 2020).

▪ Handling Methods and Stress

Low-stress handling methods are a simple way to promote the health and well-being of dairy cattle. Safer handling methods for animals are also safer for farmers, as 45% of livestock-related injuries are related to handling cattle (Canadian Agriculture Industry Reporting). Studies of dairy cow handling methods generally show negative effects of aversive handling on cow behaviour, but not necessarily on milk yield (Munksgaard et al. 2001; Rushen et al., 2001).

Most studies examining the effects of handling methods on animal productivity and welfare have been focused on the beef industry. Beef farms participating in animal handling training, whether occasionally or regularly, have been shown to use better handling techniques and, therefore, their cattle performed fewer undesirable behaviours during handling compared with that of non-trained farms (Ceballos et al., 2018a). On non-trained farms, there was also a decline in handling quality over the course of the day. Ceballos et al. (2018b) also observed that poor handling was related to high reactivity of heifers, as well as more undesirable behaviours and accidents. While they did not directly link negative handling or reactivity to pregnancy rates, poorly handled heifers had dirtier perineal regions, which was associated with lower pregnancy rates.

Here are some key do’s and don’ts adapted from Temple Grandin (Grandin, 1989; Grandin et al. 1998):

- Don’t make sudden movements, and avoid exposing cows to sudden noises, moving air and objects, and flashes of light.
- Do remain calm and alternate between ‘driving pressure’ and ‘drawing pressure’ when moving cows. This relates to their flight zone, also called the pressure zone, zone of awareness, or zone of influence. Cattle can be easily sorted through a gate by using a combination of ‘driving pressure’ when the flight zone is entered and ‘drawing pressure’ when the handler is just outside the boundary of the flight zone.
- Don’t isolate cows. If necessary, minimize the amount of time and ensure that the cow has visual contact with others.
- Don’t overcrowd cows in small pens, such as holding pens.
- Do make first experiences positive, because cows remember previous negative experiences. Cows can be trained and exposed to new situations slowly, habituating them to that experience. But if the exposure is negative, they can be conditioned to experience fear. Livestock previously handled gently will be less stressed and easier to handle in the future, which will lead to fewer injuries, better performance, and weight gain.
- Be consistent, or at least consistently inconsistent. Although animal learning is specific, animals can generalize to similar situations and can adapt to new things, but novelty and inconsistent handling generally cause stress. That being said, animals raised in variable environments are less likely to be stressed when confronted with novelty, and so it is important to slowly introduce novelty to younger animals. Calves and heifers have great potential to learn if given the chance.

Cow Health, Productivity, and Behaviour

As mentioned before, we know that animal welfare and lameness are top-ranking priorities for dairy farmers and other stakeholders. Despite that, the true prevalence of disease is often underestimated because farmers and veterinarians often focus primarily on severe cases, yet subclinical cases are much more prevalent. Regarding lameness, severe cases (mean of 2 to 4% of cows/herd) are a major focus across Canada but are less prevalent than moderate lameness (21 to 26% of cows/herd; King et al. 2016; Jewell et al. 2019), where cows still limp and likely experience pain or discomfort. Similarly, ketosis is a common disorder clinically affecting 2 to 12% cows/herd and subclinically affecting 21 to 41% of cows (Tatone et al., 2017). Subclinical ketosis is especially common after calving when energy demands are high, and cows are unable to consume enough feed to meet those demands. Subclinical mastitis contributes to 48% of mastitis costs for Canadian dairy farmers, while only 34% is due to clinical mastitis (Aghamohammadi et al., 2018).

Regardless of the health disorder, there are generally negative consequences of disease in terms of production, behaviour, and the overall health and welfare of dairy cattle. Furthermore, severe and clinical cases of disease cause obvious and outward signs of sickness, whereas subclinical diseases present without symptoms. However, even cows with moderate lameness and subclinical ketosis exhibit changes in behaviour and production (King et al. 2017a, 2018), which may be subtle but are also significant (1.6 to 2 kg/d).

Fortunately, with modern precision technologies, we can monitor cow behaviour and detect symptoms that appear to be subclinical to the naked eye. General trends for cow activity, rumination time, and milk yield are consistent between studies, whether comparing sick and healthy animals or looking within affected cows relative to diagnosis day. Despite a large variation between cows, there are also certain variables (particularly rumination time) that consistently deviate at least one day before other variables (milk yield) and may act as early indicators of disease. There are also differences across diseases such that acute health disorders (i.e., displaced abomasum and mastitis) are associated with deviations from those cows’ baseline automated milking system data, whereas more chronic disorders (i.e., subclinical ketosis and lameness) are associated with significant, but subtle, longer-term changes in milk production and behaviour.

Numerous other researchers have documented reductions in milk yield and rumination time beginning from one up to ten days before diagnosis of several disorders, such as milk fever, ketosis, mastitis, metritis, pneumonia, hock and hoof lesions, and digestive disorders (reviewed by King and DeVries, 2018). Depending on the disorder, milk conductivity may increase, whereas activity may decrease (when measured as steps per day; Edwards and Tozer, 2004). However, activity as measured by rumination collars only records the upward motion of the head, and therefore, this may not be a useful way to assess health status. Some researchers reported reductions in rumination time and activity occurring one to five days before diagnosis of metabolic disorders, pneumonia, and metritis, but others found no difference in rumination time or activity between lame and non-lame cows (reviewed by King and DeVries, 2018).

▪ Human Health and Cow Health

When people think about human and animal health, they often focus on physical health. However, we must also consider our mental and emotional health. Farmer mental health is a key component of agriculture and an emerging area of concern, as was demonstrated in the 2019 Report of the Canadian House of Commons Standing Committee on Agriculture and Agri-Food, “Mental Health: A Priority For Our Farmers”.

Canadian farmers experience higher levels of stress, anxiety, and depression than the average citizen (Jones-Bitton et al., 2019). This trend along with higher rates of suicide are unfortunately seen around the world because farming is one of the most physically dangerous and mentally stressful occupations (Milner et al., 2013). There is also evidence that livestock producers may experience greater rates of stress-related symptoms and suicide than crop producers (Kanamori and Kondo, 2020), making the need for mental health support even more important.

Health is just one of the many factors that contributes to the well-being of human and non-human animals. For humans, there are eight dimensions to our overall well-being: physical, mental/emotional, spiritual, social, occupational, financial, intellectual, and environmental. As you can see, there are many aspects of well-being to think about.

There are also connections between human and animal well-being. According to pig and dairy farmers in Norway, taking care of their own well-being ranked as the most important way to improve animal welfare, but it was the most difficult action to put into practice (Kaupinnen et al., 2010). Hansen and Østerås (2019) found that dairy farmers who felt stressed, lonely, or weary, scored lower on their animal welfare indicator (an overall scores looking at production, culling, and cow health); alternatively, herds scored higher on their animal welfare indicator when the farmer reported better occupational well-being (including work satisfaction, income, optimism about the future and control, and feeling appreciated as a farmer).

In our study of robotic milking herds, we found that those who worked mostly alone on the farm had greater anxiety and depression levels than those who worked with others (King et al., 2021). Farmers who also used automated feeders had lower stress, anxiety, and depression scores, compared with those feeding conventionally. It is also possible that dairy farmers using robotic milking systems may be experiencing less stress, anxiety, and depression than the average Canadian farmer (compared to all commodity groups surveyed by Jones-Bitton et al., 2019). However, there may also be negative consequences of using automation and the associated alerts and alarms, which may be new sources of stress in addition to the financial stress of new investments and learning to use new systems. Tse et al. (2018) found that switching to robotic milking systems improved producers’ time flexibility, ability to manage cow health and employees, and their quality of life and that of their cows. In our study, cow lameness prevalence was related to farmer stress and anxiety scores (King et al., 2021), supporting the notion that human and animal health are connected.

Future research in this area will help producers to think and talk more about their mental health and that it can improve our understanding and ability to manage farm stress, enhancing the well-being of farmers and animals, their productivity, efficiency, and profitability. Openly discussing these challenges and our shared values of animal welfare and sustainability enhances public trust and compassion towards farmers. Most importantly, to ensure the success and sustainability of animal agriculture, we must support the health and well-being of both farmers and cattle.

▪ Conclusions

This proceedings chapter emphasizes the relationships between management, housing, handling, and cow stress. Stress can be physiological or psycho-social; therefore, we must consider cows' physical and social environments and their behaviour. Stress can affect cow behaviour, health, and re(production). Inversely, poor health, even it is if only a moderate or subclinical health disorder, can act as a stressor and negatively impact cow behaviour and production. Finally, farmers should remember to take care of their own physical and mental health, as it will also have positive benefits for their families and animals.

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Managing Health and Rumination Data: Getting the Most out of Your Technology

Jake Vermeer

Vermeer's Dairy Ltd, Email: jake@vermeersdairy.com

Take Home Messages

- Rumination technology will allow for enhanced, in-depth fresh cow monitoring.
- Integrating rumination technology into existing management software makes using the technology simpler and opens the door to increased efficiencies.
- Tracking and storing rumination data will unlock new genetic metrics that farmers can use to identify profitable animals.

Farming today is not what it was 50, 25, or even five years ago. The pace of change has never been this fast and it will never be this slow again. Technology moves at lightning speed, but the slug of our busy day-to-day lives as dairy farmers creates an overwhelming question: how can I get more out of this technology? It's easy to find a grant and purchase that next piece of cutting-edge technology, be it a new feed program, milking robot or rumination technology. Producers may think that the initial investment is the hard part, when it is in fact extracting the return on investment that is most challenging.

The purpose of this paper is not a sales pitch; I have yet to receive any sort of commission for helping in the sale of rumination collars. I believe that in sharing my story of how our farm uses this technology, more farms will begin the conversation of 'how to increase return as well as animal welfare'. The cows are telling a story; we just need the means to listen.

We first incorporated rumination technology on our farm as an investment due to expansion. We had had leg pedometers for identification and heat detection purposes for 12 years and had begun to see that ~20% of the pedometers were failing and needed to be replaced. Coupled with a herd expansion, we decided that there was an opportunity to upgrade the existing technology and looked at neck collars with rumination technology. I quickly found a government grant to cover 60% of the cost and it seemed like an easy investment. Over the next eight weeks we converted from pedometers to neck collars on all the cows, and we were off to the races.

Fast forward to today. Most of my days begin by logging into our computer and checking DairyComp305 (DC305) for alerts and attention alarms. I scroll through the fresh cow list and check each fresh cow's rumination graph. I find by checking each one individually as opposed to only the cows identified with 'attentions', that I remain engaged as to who is fresh and where they are headed. Our farm has always understood that fresh cows are key to any successful operation. Three years ago, we were doing daily ketosis testing and temperature checks to detect problem cows early, but it meant longer lock up times and more labour. Now we never lock fresh cows and are able to track their progress at a micro-level. It sounds intense but tracking a cow's hour-by-hour rumination progress can help mitigate a lot of traditional fresh cow problems. Here are some examples of cows that have traditional issues as shown by rumination technology (Figure 1).

Figure 1: Information on cow health derived from rumination collars.

The above cow had a calcium deficiency after calving, she was treated, and a few days later we saw improvement. Notice that her eating graph was very low but her rumination remained strong; this indicated to me that she wasn't going to the bunk (obviously since she was down) but that the feed we were giving her was still causing her to ruminate.

We often see cows with a drop in rumination on the day of calving, which is normal. By all accounts, the calving period is a stressful time for cows. I caution producers to not overreact on the day of calving in terms of treating cows as a result of analyzing rumination graphs. It's on day two that I start to give credence to the graphs and start to watch the cows in terms of getting them back to pre-calving rumination levels. To be clear, rumination and eating time technology has not replaced walking through the fresh pen and using traditional cow signals to monitor cow performance, but it has become a translator for the cows to tell us what's going on.

One of the most important ways to get more out of rumination technology is to integrate the data into existing herd management software. One of my greatest pet peeves is having to use multiple software platforms in order to access my data. For us, we have GEA and Alta Genetic Nedap collars (IFER Tags). We also use DC305 on our farm for all of our herd management. When we invested in the technology, I made it clear to all parties that I wanted the two platforms to communicate and create a seamless user experience. We were able to accomplish most of this and we now have Nedap alerts and attentions being funnelled into DC305. It may not sound important, but it's been one of the main reasons I've been able to extract more out of the technology.

As a result of the integration, Nedap now sends the heat and rumination alarms three times per day. The heats trigger auto sorts and cows are bred after each milking. A report is generated from DC305 containing all cows with heat attentions that a member of our team uses to breed. The rumination and eating time alarms are also downloaded in a similar fashion and are auto sorted and checked using our health alarm SOP. When the data, such as a heat alarm, enters into DC305 we tag it on the cow card as '*HEAT NEDAP'*. This allows us to see cows during the involuntary wait period to make sure that they are cycling. Cows who do not have a 'tag' or event on their cow card are sorted onto the vet list prior to herd health. This sort of behaviour may indicate a cow who is cystic or anovular or may simply just be a missing collar. Either way, the cow is checked, and subsequent action is taken.

The same is done for health alarms. A cow who has a rumination or eating time alarm has a 'Dx.Attn' (Disease Attention) event entered onto her cow card (Figure 2). This allows us to track and store an individual cow's alarms, which is why we need DC305. Usually, your rumination technology data is linked to the device itself; therefore, when you change a collar or cull a cow, that data is lost and overwritten onto the new cow. By storing the data on DC305 it allows a unique opportunity to review long term data and identify trends, even genetic ones.

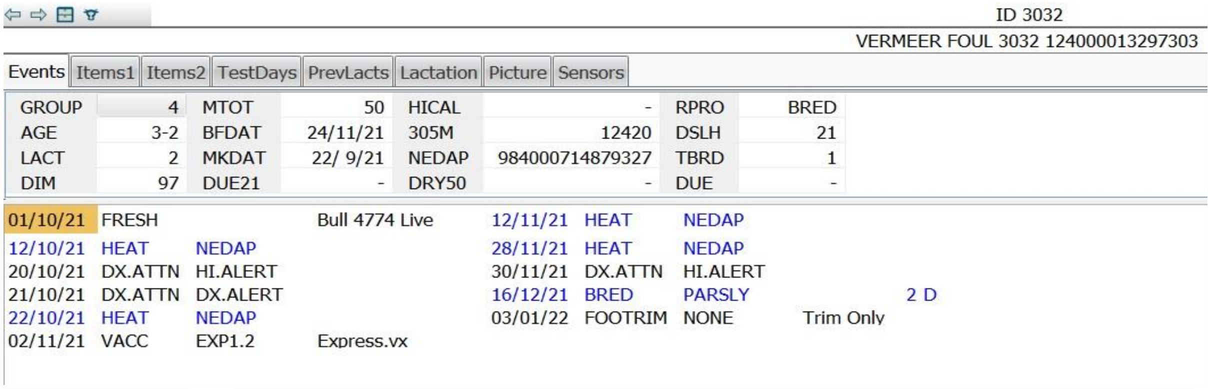


Figure 2: A DC305 cow card; the cow had multiple heats before her double Ovsynch breeding.

By creating an item called Dx.Attn we are able to see genetic trends within our herd in relation to health alarms. With the help of our genetic advisors at Alta Genetics we were able to distinguish the following trends.

We split our 1st lactation cows into two groups by productive life (GPL). The top group averaged a 3 for PL and the bottom a 1.3 for PL (Figure 3). We then compared the top and bottom groups for health events, including Dx.Attn. The top PL group had significantly less traditional health events but also way less Dx.Attn alarms, showing that our alarms are identifying genetic trends, something that we hope can become industry wide (Figures 4a and 4b).

By GPL	Pct	Count	
3.00	53	172	>=2.2
1.30	47	154	<=2.1
Total	100	326	

Figure 3: Distribution of cows based on productive life (PL)

#	Event	Total	Jan22	Feb22	Mar22	Apr22	May22	Jun22	Jul22	Aug22	Sep22	Oct22	Nov**	Dec21
1	FRESH	159	14	14	9	8	16	7	22	16	11	13	11	18
12	ABORT	12	0	0	0	1	1	1	3	1	2	2	1	0
13	DNB	9	0	0	0	0	0	0	1	0	7	0	1	0
36	LAME	50	3	1	7	4	4	5	7	6	8	1	2	2
37	MAST	7	1	0	0	0	2	1	2	0	0	0	0	1
59	DX.ATTN	369	14	19	37	45	31	27	37	40	28	60	24	7
	TOTALS	606	32	34	53	58	54	41	72	63	56	76	39	28

Total cows listed : 159

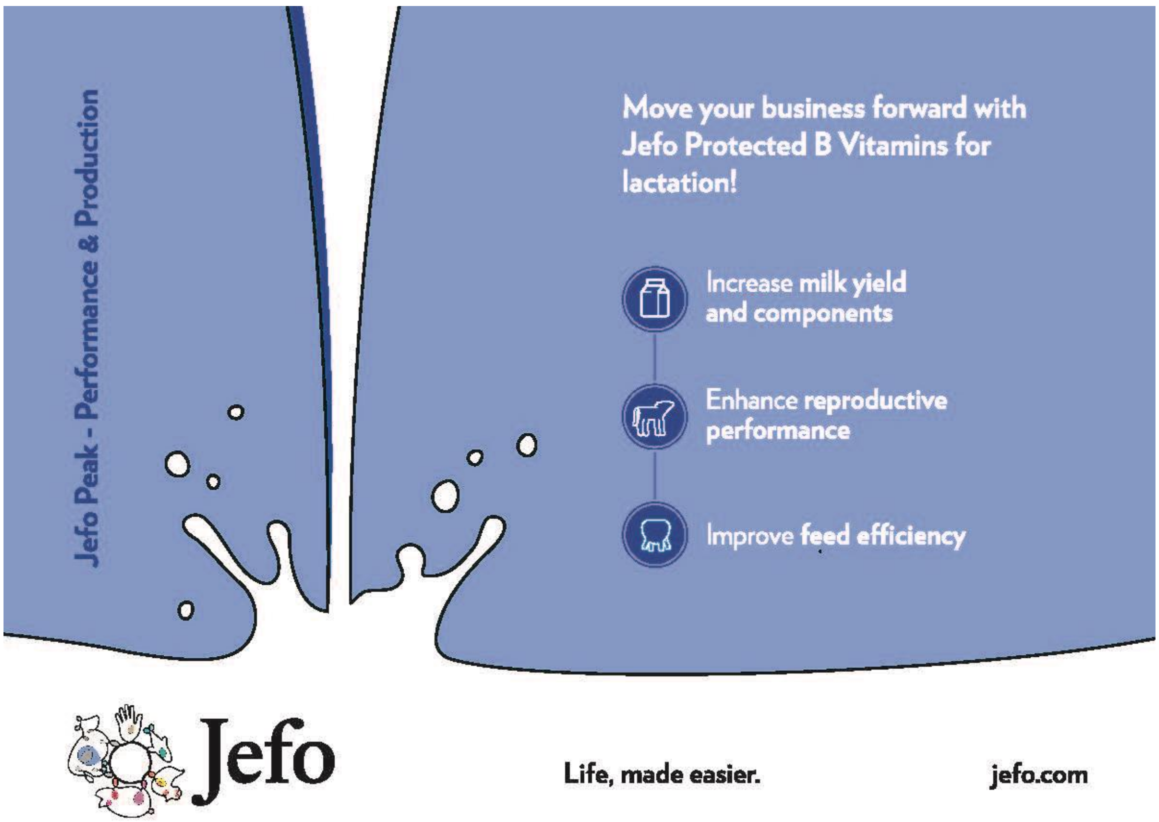
Figure 4a: Top Productive Life Group

#	Event	Total	Jan22	Feb22	Mar22	Apr22	May22	Jun22	Jul22	Aug22	Sep22	Oct22	Nov**	Dec21
1	FRESH	167	11	12	19	15	15	9	16	22	11	17	10	10
12	ABORT	8	0	0	0	0	0	1	1	0	3	1	2	0
13	DNB	8	0	1	0	2	0	0	0	0	2	2	1	0
14	SOLD	25	1	4	2	2	3	3	2	3	2	0	3	0
15	DIED	5	0	0	0	0	2	0	0	2	0	1	0	0
36	LAME	42	5	1	3	7	5	6	5	2	2	5	0	1
37	MAST	6	1	0	0	0	0	3	0	2	0	0	0	0
38	METR	1	0	1	0	0	0	0	0	0	0	0	0	0
42	RP	2	0	1	0	0	0	0	0	0	0	0	0	1
59	DX.ATTN	503	17	18	43	39	49	23	60	53	78	82	35	6
	TOTALS	767	35	38	67	65	74	45	84	84	98	108	51	18

Total cows listed : 167

Figure 4b: Bottom Productive Life Group

Using rumination technology has allowed us to micromanage our cows, especially around the fresh cow period, while also allowing us to create standard operating procedures for employees to follow and maintain optimum herd health. By integrating the technologies into existing software platforms, we've been able to streamline efficiencies, and track and store data long term. I believe that there is a long-term place for sensory data with dairy cows and we are only just scratching the surface.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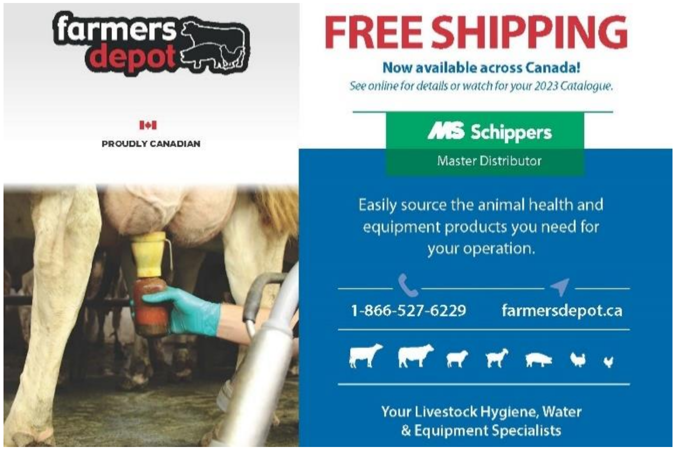
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Beef on Dairy Crosses: Diversification and Income Potential

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Take Home Messages

- Beef on dairy crosses are displacing much of the fed cattle supply previously attributable to Holstein steers.
- Beef on dairy programs represent a significant opportunity for dairies to increase income.
- The longer feeding period of beef on dairy crosses compared with that of native beef animals creates unique challenges in terms of liver abscess rates and exposure to feed costs.
- Beef on dairy programs are positioned to collect and transmit data up and down the value chain that should ultimately drive genetic improvement and create sustainable economic advantages for value chain participants.

Introduction

In the U.S., Holsteins have historically accounted for 17 to 22% of fed beef production. Not all slaughter plants harvested Holsteins, but all three major beef packers were involved in the harvesting of fed Holsteins. Packer contracts were offered at a defined future basis relative to beef cattle. The selling discount ranged from $6 to $10/hundredweight (100 lbs; cwt) dressed which is approximately an $8 to $10/cwt discount live. When Tyson decided to stop slaughtering fed Holsteins the market for day-old Holstein bull calves collapsed. The basis between fed beef cattle and fed Holsteins widened to $15 to $25/cwt discount live depending on geographical location. Tyson's decision incentivised U.S. dairies to look for alternative breeding strategies to increase the value of the day-old bull calf.

Perspectives

Feedlot Perspectives

Crossbreeding beef on dairy results in greater average daily gain, improved feed conversion, improved quality grade, and improved carcass cutability compared with pure dairy animals. The basis from fed beef to fed beef on dairy varies from par to a $3/cwt discount. Beef on dairy is an opportunity to establish a consistent supply of feeder cattle that hold an advantage over the straight dairy animal in terms of feeder value. Within dairy breeds, Holsteins have the challenge of packer reluctance to harvest resulting in an extreme fed basis that limits feeder value. Straight Jerseys have little to no value as feeder animals. The average daily gain in a straight Jersey male is very low, dress is poor, and feed conversion is high. Clearly beef on dairy results in a more valuable feeder compared to straight dairy. However, it does have challenges compared with a native beef animal. Typically, placement weight is lighter than for native beef cattle, and average daily gains are lower resulting in greater days on feed. Long-fed cattle have challenges with liver abscesses that can create justification for a negative basis from the packer. Packer perspectives are discussed below but maintaining a par-to-positive fed basis is what feedlots will need to maintain a successful beef on dairy fed program. A wide fed basis has a significant impact on $/head profitability. Feed cost is the greatest expense at the feedlot, and in long-fed cattle small changes in feed conversion have a big impact on the $/head profitability. Feedlots are interested in procuring feeders that have been genetically selected for improved feed conversion. Long term success of beef on dairy programs from the feedlot perspective will be a function of purchase price, daily gain, feed conversion, and fed basis relative to that of a native beef animal.

Dairy Perspectives

Use of sexed semen within the dairy industry allows dairies to have an increased supply of replacement heifers out of top dams. Beef crossbred males provide greater value to dairies compared with purebred dairy males. The threshold for a sire to be used on a dairy is that conception rate is high, calving ease is high, and gestation length is low. These simple requirements from the dairy standpoint provide opportunities to use the best genetics on the beef side.

Packer Perspectives

To meet the phenotypic requirements for Certified Angus Beef (CAB), beef on dairy cattle must be black hided. Packers are looking for beef that can be marketed as CAB. Beef on dairy cattle typically marble well, producing beef that is 75-80% AAA (Choice) or better. Crossing beef with dairy results in improved dress and carcass cutability compared with straight dairy. Beef on dairy animals have better muscle conformation compared to straight dairy, and the muscle-to-bone ratio is comparable to native beef animals. So, the cross is highly advantageous over straight dairy. Packers continue to quantify carcass cutability and the shape of the carcass relative to native beef cattle to determine what (if any) fed basis to apply. As days on high concentrate ration increase, so does the incidence of liver abscesses. This is one of the greatest negatives for beef on dairy compared with native beef programs. The incidence of liver abscesses between straight Holstein and beef on dairy cattle is comparable, but the gain advantage could decrease days on feed for the beef on dairy animals, thus lowering their risk for developing liver abscesses. Beef on dairy management results in lower greenhouse gas emissions and a smaller carbon footprint. There is a conflict because the management practices that result in positive impacts on emissions and carbon footprint also contribute to greater liver abscess incidence. The industry has yet to determine the value of lowering emissions and reducing its carbon footprint.

Genetics Company Perspectives

There are approximately 10 million dairy cows in the U.S. and 1 million in Canada. If 30% of matings are beef on dairy, with three straws of semen required per live birth, then there is opportunity to use 9-10 million doses of beef semen. There are huge opportunities to generate true progeny differences and isolate outlier sires in order to optimize feeder performance.

▪ Advantage to Beef on Dairy System

In native beef cattle production systems, rarely are heath outcomes, performance through all management phases, and carcass data linked to sire. In the beef on dairy system the data can all be linked. True progeny differences can be determined with enough progeny per sire to overcome inherent variation due to management.

▪ Opportunity

The opportunity exists to create three to four million beef on dairy feeders annually as part of a true (and consistent) supply chain. Opportunities also exist to collect, transmit, and use data collected by the various participants and segments of the value chain to drive and measure continued genetic improvement of the beef on dairy population.


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