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The Future of Sustainability in the Dairy Industry: A Focus on Net Zero

Sara E. Place

Associate Professor, AgNext, Colorado State University, 1171 Campus Delivery, Fort Collins, CO, USA 80523; email: sara.place@colostate.edu

■ Take Home Messages

- Greenhouse gas neutrality or Net Zero for dairy production will require significant changes in emissions, especially reductions in methane emissions.
- More evidence-based solutions are required to reduce emissions.
- Technical solutions without the right financial incentives or focus on social acceptability are likely to fail to achieve wide scale adoption.

■ Introduction

Sustainability is a growing topic of interest; however, it could be argued sustainability is a label for issues that the dairy industry, and agriculture more broadly, has been grappling with for decades. Those issues include environmental stewardship, the long-term viability of farm businesses and communities, the need for high quality human nutrition, and social responsibility toward people and animals in the farming system. While the broad categories of sustainability issues may be relatively unchanged, changing societal expectations and new challenges have been added to the long list of considerations dairy producers face. One such example is climate change and efforts to reduce the climate impacts of dairy production.

■ Greenhouse Gas Emissions from Dairy Cattle Production

The U.S. and Canadian dairy industries have set ambitious goals to achieve greenhouse gas (GHG) neutrality and Net Zero emissions, respectively, by 2050. To better understand these goals, we must understand the GHG emissions profile of dairy cattle production. Rotz et al. (2021; Table 1) evaluated U.S. dairy cattle production and determined the activities with producing milk from dairy cattle (not including impacts from the dairy supply chain beyond the farm gate like processing) produced 99 million metric tons of carbon dioxide equivalents (CO₂e) in 2019. Thus, U.S. dairy cattle production represented around 1.5% of total U.S. greenhouse gas emissions in 2019.

Importantly, 62% of the CO₂e emissions emitted from U.S. dairy cattle production are methane emissions, both from enteric and manure sources. This presents both an opportunity and challenge for achieving climate goals because methane is potent at trapping heat but has a short atmospheric lifetime. The practical reality is that strong reductions in methane emissions from dairy production can reduce the sector's warming contribution in the near-term; however, increases in methane emissions can mean contributions to increased warming. As a result, reductions in methane emissions are a key opportunity for dairy, especially as zero methane emissions are not required to achieve no further warming contributions from the industry (Place et al., 2022).

Table 1. Greenhouse gas emissions from U.S. dairy cattle production (Rotz et al., 2021)

Emissions Source	Percent of Total ¹
Enteric methane emissions	43
Manure methane emissions	19
Manure nitrous oxide emissions	6
Cropland nitrous oxide emissions	4
Indirect nitrous oxide emissions	3
Resource production ²	22
Anthropogenic carbon dioxide ³	3

¹The 100-year global warming potential values of methane and nitrous oxide were 28 and 265, respectively.

²The impact of producing farm inputs including fuel, electricity, lime, machinery, purchased feed, seed, and chemicals.

³Carbon dioxide emissions from liming and fuel combustion on farm.

However, reductions in methane emissions will require significant changes from business as usual because methane emissions from U.S. dairy cattle enteric fermentation and managed manure have increased since 1990 (Figure 1). In short, historic emissions trends continued into the future will not result in achieving GHG neutrality nor Net Zero for the North American dairy industry.

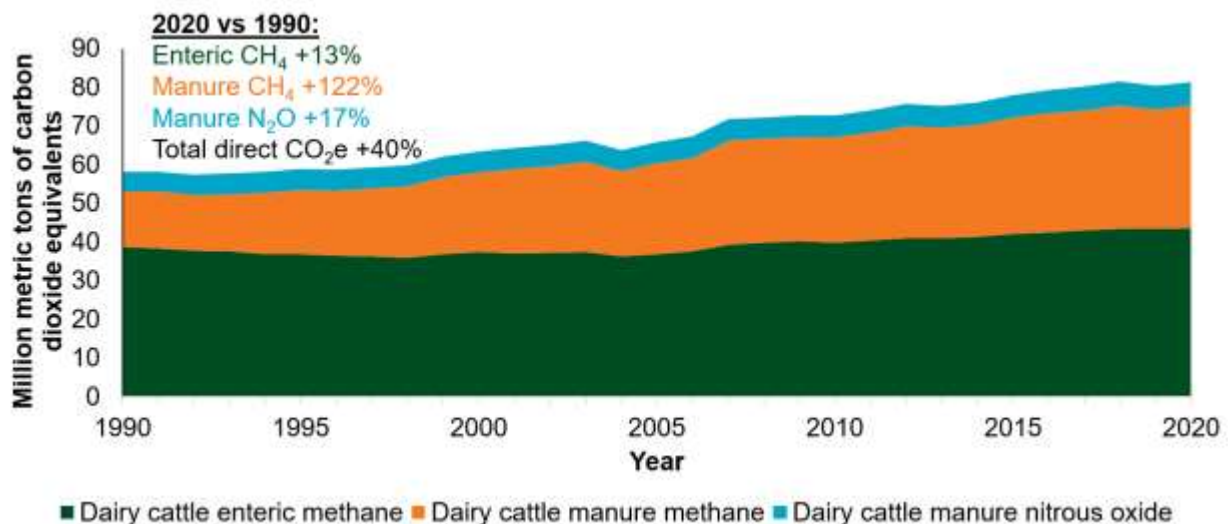


Figure 1. Trends in GHG emissions from U.S. dairy cattle according to the U.S. Environmental Protection Agency (EPA, 2022).

Solutions Need to Consider Adoption

Increasing the number of evidence-based solutions to reduce GHG emissions from dairy cattle production is critical to achieve climate goals. However, just as important as research and development activities to discover new technical solutions are economic and social systems that allow for adoption and long-term viability of solutions. Consideration needs to be given to how potential solutions will impact quality of life of producers and dairy workers (e.g., will a technical solution add complexity to production and labour requirements?). Additionally, we need solutions that can at least be cost neutral or ideally improve margins for cattle producers. For example, as demonstrated in Figure 2, if a feed additive can reduce enteric methane emissions from lactating dairy cattle by 20%, but has no positive effect on productivity, producers

will need to receive a carbon price premium to simply breakeven. If the feed additive costs US\$0.15 per cow per day, the dairy producer will need to be paid a carbon price of US\$75 for the reductions they generate by adopting the feed additive. For context, current voluntary carbon prices are US\$2-3 in the U.S. Without adequate compensation, the cost of new feed additives to reduce enteric methane emissions would add to the total costs of milk production, negatively impacting the financial sustainability of dairy cattle production.

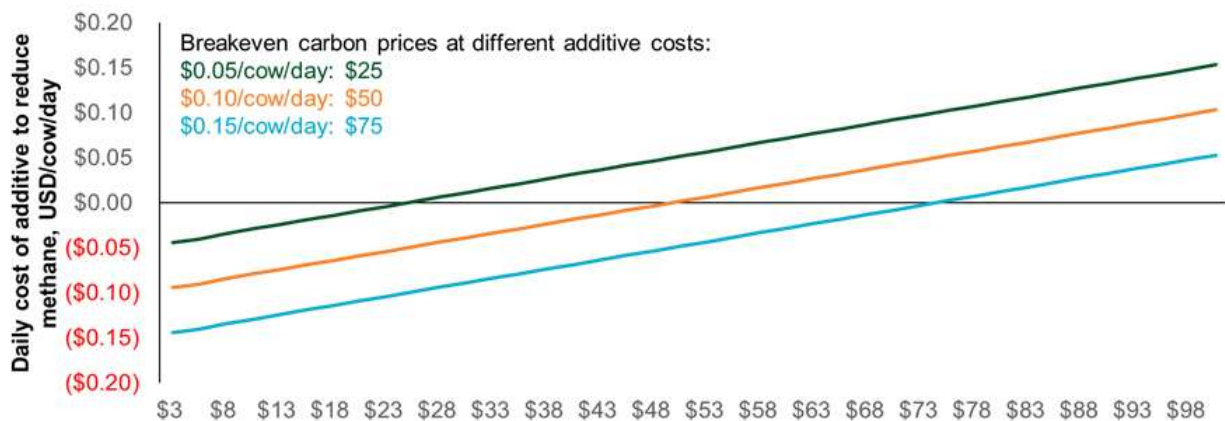


Figure 2. Enteric mitigation example with a 20% reduction per lactating cow in enteric methane emissions and no productivity effects. Assumes 405 g of enteric methane emitted per cow per day. Carbon prices indicate the price the dairy producer receives.

■ Conclusion

In conclusion, achieving climate commitments will require significant departures from business-as-usual dairy cattle production. New technologies and management strategies are required; however, without considering the economic and social impacts of adopting new technologies, wide scale adoption will likely be limited.

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Supplying Canadian Demand: Economic Sustainability and Supply Management

Matthew Gaudreau

Canadian Dairy Commission. Email: matthew.gaudreau@cdc-ccl.gc.ca

■ Take Home Messages

- Economic sustainability is not just about costs and profit; it is also about the rules of the marketplace.
- Dairy supply management is a set of rules and organizations that shape the market for dairy in Canada for sustainability.
- The mandate of the Canadian Dairy Commission sets the objectives of the system to provide fair returns to efficient producers and ensure stable supply to consumers.
- The cost of production survey, milk component pricing method, and responsiveness to crisis are all key elements of the sustainability of supply management.

■ Introduction

I was invited to the Western Canadian Dairy Seminar as part of the panel on sustainability in Canadian dairy. While my fellow panelists from Ducks Unlimited Canada and Dairy Farmers of Canada will focus on environmental and social elements of sustainability in dairy, my task is focus on economic sustainability.

When we think about the idea of economic sustainability in dairy, we often talk about farm accounting, farm management, and farmer livelihood. From that point of view, an economically sustainable dairy farm is one that is profitable over time. But economic sustainability is not solely about the financial health of individual dairy farms; the financial health of a farm depends not only on the choices made by farmer owners managing their operations, but also on the rules that set up the marketplace.

In this paper I will look at Canada's supply management system as a set of economic rules that support economic sustainability in the broader Canadian dairy market. These rules are key to creating a marketplace that prioritizes stable supply of local milk to the country and ensures that efficient dairy farmers in Canada can make a living. By remunerating farmers fairly and ensuring the market demand is always served, the supply management system sets out the parameters for an economically sustainable dairy marketplace.

First, we turn to a brief discussion of international research on sustainability in dairy. Then we look more closely at the idea of economic sustainability and why institutions and rules matter. Finally, I will introduce the key economic rules of supply management and the organization that enact these rules. The paper will close with a brief review of some of the key challenges for economic sustainability of dairy in Canada.

■ What does Sustainability Mean for Dairy?

Arvidsson Segerkvist et al. (2020) conducted a literature review on overall sustainability in dairy farming. The authors see sustainability as having three interconnected elements: environmental, social, and economic. All three elements need to be considered together to get a full picture of sustainability. The authors note that there are surprisingly few studies regarding dairy that cover the three dimensions of

sustainability simultaneously; they found 35 studies in their final review and only 11 of those studies dealt with all three elements of sustainability.

Of note, only two of the studies reviewed by the authors dealt with dairy in Canada! The studies focused on countries in Europe, North America, and Oceania but very little on Canada. In this context, this panel at the Western Canadian Dairy Seminar is well placed to pick up on discussion and perhaps inspire more engagement on this important subject.

As you can see in Figure 1 extracted from the article, most of the study of sustainability in dairy is focused on the social element. However, the social, economic, and environmental factors all tend to be closely linked. For example, farmers decisions and labour are described as social but clearly have economic implications for profit and optimization of farm operations. Likewise, said decisions have an impact on environmental factors such as energy use and soil health.

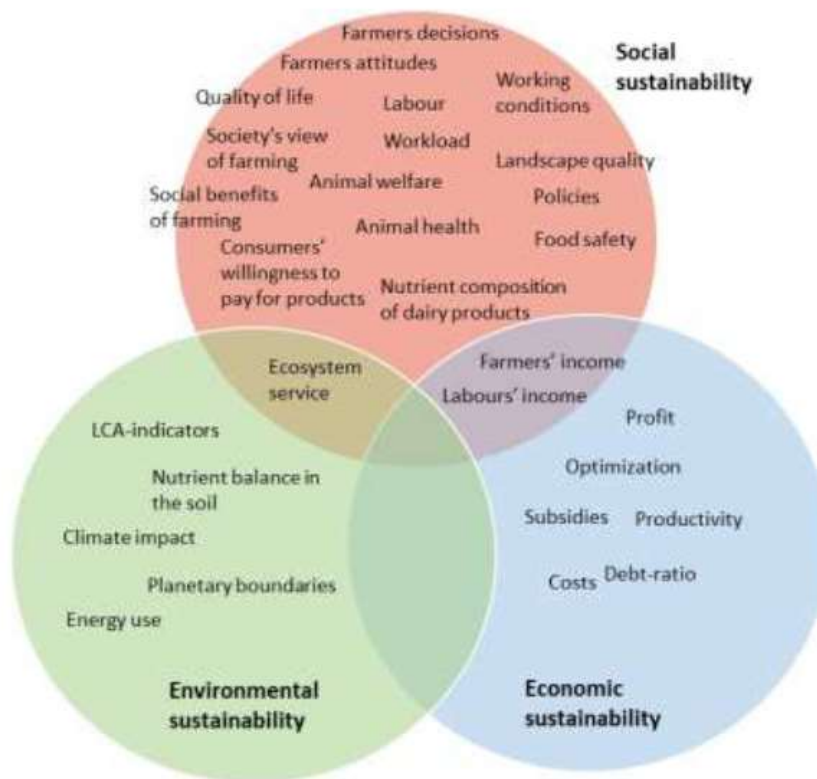


Figure 1. Categorized keywords based on data extracted from papers covering, or mentioning, different aspects of sustainability in dairy farming (Arvidsson Segerkvist et al., 2020).

This paper will focus on economic sustainability and the different ways we can understand the concept. More specifically, in the next section we will introduce a broad understanding of economic sustainability that recognizes the importance of the institutions that design how a given market operates. Even though the focus is on economic rules, the concept applies equally to related questions of environmental and social sustainability.

▪ What does Economic Sustainability Mean for Dairy?

While there is some literature on farm profitability and sustainability, there is next to no discussion of the economic institutions that underpin the dairy economy. Economic institutions are another way of saying the laws, rules, and regulations that shape the dairy market in any given country (North 1990). In this paper I refer to institutions and rules interchangeably.

Arvidsson Segerkvist et al.'s (2020) review shows that economic sustainability in dairy is least well defined. The literature focuses narrowly on producer labour and farm profitability. For example, an economically sustainable dairy farm is one where farm income is sufficient to make a profit over time, accounting for debt levels.

Of course, a farm's ability to cover its costs and provide a living are key economic factors in ensuring sustainability over time. However, this view of economic sustainability is narrow. Not only are farms important but the full supply chain is key to ensuring healthy economic relationships between farmers, processors, retail, food service, and end consumers.

To put it differently, economically healthy farms not only have to manage on-farm costs, but they also depend on predictable and stable markets for their product. As Borawski et al. (2020) put it in the context of the European Union, "the need to stabilize, sustain and develop a competitive market is essential." But the way that countries set up the rules that govern a competitive market is not always the same. Each major dairy producing country has quite different laws and regulations for milk payment and farmer income stabilization, and for governing relationships between different links in the supply chains.

While the dairy regulatory structure is different in each country, the market logistics are always similar for dairy. There is a maxim that's often tossed around that 'you can't just turn cows on and off like taps.' Indeed, in many countries, short term fluctuations in supply and demand can cause wide swings in revenues received by dairy farmers.

Arvidsson Segerkvist et al. (2020) do not specifically advocate a supply-chain perspective of economic sustainability. However, they do specifically note that none of the existing literature they encountered on economic sustainability in dairy farming include formal analysis of institutions or rules that govern the marketplace for dairy. This shortcoming is significant. Economic institutions give rise to the marketplace dynamic in which a dairy farm must operate.

In Canada, the supply management system makes the context of economic sustainability unique precisely because the economic institutions are different than most dairy producing countries. In the next section, we will look at the economics and some of the organizations that help Canada's dairy market to operate.

▪ Supply Management and Economic Sustainability

Supply management was introduced in 1966 to help stabilize dairy markets. As Statistics Canada once expressed,

"...supply management regulates domestic production and imports to ensure that the supply of that commodity matches demand, and that the prices paid to farmers are steady over time, cover their production costs, and leave them with a pre-determined, predictable income. In return, processors and consumers are guaranteed a consistent supply of a top-quality commodity at a stable price" (Scullion 2006).

To achieve this stability in the Canadian market, there are three main economic pillars to supply management. These three pillars form the key parameters of the market in Canada:

1. Managed Supply

- Canadian milk production is based on a measure of total requirements of butterfat (BF) in Canada minus markets dedicated to dairy imports under trade agreement (in BF equivalent). Requirements are calculated monthly, and producers operate on a system of seasonal production credits to stabilize supply with demand. The Canadian Dairy Commission provides stakeholders with forecasts to assist in planning for anticipated future demand.

2. Managed Prices

- Provincial Milk Marketing Boards (PMMB) manage annual price changes through an established formula that accounts for the Cost of Production (COP) and the Consumer Price Index (CPI) measuring overall inflation in the economy.

3. Controlled Imports

- Canada maintains tariffs on most imported dairy products to reserve for the market for domestic actors.
- Global Affairs Canada manages the Government of Canada's trade commitments regarding dairy product imports.

The effect of dairy supply management is to ensure that the vast majority of cow's milk is produced locally on Canadian dairy farms, that dairy products are processed in Canada, and that Canadian consumers have a stable domestic supply of dairy product. At the federal level one of the key institutions is the Canadian Dairy Commission Act.

Canadian Dairy Commission

The CDC's mandate is two-fold and directly related to creating an economically sustainable Canadian dairy sector. The CDC's mandate is:

- Fair Compensation
 - Provide efficient producers of milk and cream with the opportunity to obtain a fair return for their labour and investment.
- Efficient Supply
 - Provide consumers of dairy products with a continuous and adequate supply of dairy products of high quality.

Together, fair compensation for producers and efficient supply to consumers represent key parameters to ensure a sustainable market for dairy products in Canada. By ensuring that efficient producers are compensated for their out-of-pocket costs as well for their labour and investment, farmer livelihoods are prioritized. By ensuring a continuous supply of high-quality dairy products (and the milk needed for them), consumer demand is also prioritized.

While the mandate is expansive, it is important to note that the regulated portion of the market is the price of milk components sold from PMMB to individual processing companies. The relationship between processing companies and their clients is not subject to the regulations specific to supply management.

The CDC operates as part of the federal component of the supply management administration alongside PMMB and governments who make up the provincial components.

The following websites provide more information on the CDC:

- [Mission, Mandate and Values | Canadian Dairy Commission \(cdc-ccl.ca\)](https://www.cdc-ccl.ca/en/mission-mandate-values)
- [The Canadian Dairy Commission: A 40-Year Retrospective](https://www.cdc-ccl.ca/en/the-canadian-dairy-commission-a-40-year-retrospective)
- [2022/2023 Annual Report \(cdc-ccl.ca\)](https://www.cdc-ccl.ca/en/2022-2023-annual-report)

Cost of Production

The CDC's COP survey measures the national weighted average cost of producing a hectolitre of milk on the farm in Canada. The 2023 sample, which will be processed this spring, covers 231 farms of various

sizes across the country. The COP is an important part of the CDC's mandate as it seeks to provide a reference point for the cost of producing milk on Canadian farms, including cash costs, labour costs, and capital costs.

As mentioned at the beginning of the paper, an economically sustainable farm is not only one that can cover its accounting costs but must also provide a livelihood for farmers. To this point, the COP survey includes producer and family labour hours, as well as the opportunity cost of a farm's investment costs. In other words, the COP assumes that a farmer should get paid and not just cover cash outlays. The measurement of the COP in Canada therefore has economic sustainability in mind for dairy producers in the country.

Further information on the mechanics of the CDC's COP study and the latest results can be found here:

- [Process for the Annual Cost of Production Survey and Pricing Milk at the Farm Level | Canadian Dairy Commission \(cdc-ccl.ca\)](#)
- [Cost of production survey | Canadian Dairy Commission \(cdc-ccl.ca\)](#)

Milk Component Pricing

The COP, however, is not the only input in determining the price of milk components. Rather, annual changes to the price of milk components paid by dairy processors to dairy producers under supply management are established through a transparent and predictable formula:

50% annual change in indexed COP vs. 50% annual change in CPI

Having a predictable formula assists actors all along the supply chain in planning their business operations for the coming year. Given that most prices in Canada are in effect for an entire year, this also lends itself to stabilizing the revenues received by producers.

While the formula is a rule intended to create stability, sometimes there are extenuating factors that require a temporary deviation from the formula. When such events pop up, there are additional mechanisms with known parameters to respond to sudden market changes and temporarily adjust prices accordingly. For example, in 2022 the on-farm cost of animal feed, fuel, and fertilizer suddenly spiked during the period of wide inflation. In this case, industry stakeholders invoked the exceptional circumstances mechanism to request a mid-year price review. The result was a pricing advance that helped to smooth price increases out over the year rather than facing one larger increase.

For more information on

- Milk classification:
 - [Harmonized milk classification system | Canadian Dairy Commission \(cdc-ccl.ca\)](#)
- Milk class pricing
 - [How is the price of milk set in Canada? | Canadian Dairy Commission \(cdc-ccl.ca\)](#)
 - [Canadian milk class prices \(February 1, 2023\) - agriculture.canada.ca](#)

Canadian Milk Supply Management Committee and Milk Pooling

A key component of the supply management system, one that's not talked about often, is the lasting cooperation between provinces and regions to plan milk production, coordinate activities, and engage with stakeholders. The Canadian Milk Supply Management Committee (CMSMC) and the P10 milk pool are federal-provincial bodies that serve exactly that purpose. Made up of the ten provinces, the CDC on behalf of the federal government, and stakeholder observers, this committee is an entity that enables communication regarding the rules and operations of dairy supply management.

The reason for mentioning this entity is to make clear that carrying out the economic rules of supply management require constant communication between actors along the supply chain. Whether among PMMB, between producers and the processing sector, or among broader stakeholder groups, the CMSMC provides a key forum to ensure smooth operations of the sector.

Some recent examples of successes at the CMSMC and the P10 milk pool are squarely focused on economic sustainability, although we seldom label it as such.

During the COVID-19 crisis in early 2020, a sudden change in the market occurred. People were suddenly cooking at home, meals out almost halted, and severe supply chain and logistical issues appeared due to increased public health protocols. The CMSMC played a valuable role in gathering and sharing market information to help anticipate changes in overall demand for dairy products in Canada. Because of the cooperation and transparent discussion between stakeholders regarding challenges faced, actors along the supply chain were able to adapt their behaviour in a time of uncertainty and the Canadian market was served without interruption.

In November and December 2022, flooding hit the Fraser Valley in British Columbia, severely affecting dairy farms and milk collection operations. Through the CMSMC and regional revenue pooling agreements, dairy producers from across the country were able to work together to provide relief to affected farms, stabilizing their incomes during the emergency. Similar incidents were experienced in other provinces over the last years, with offers of assistance at the ready. Such collective action provides a layer of added security to dairy farmers who are increasingly affected by severe weather.

For more information on the CMSMC and milk pooling agreements:

- [The Canadian Milk Supply Management Committee | Canadian Dairy Commission \(cdc-ccl.ca\)](https://cdc-ccl.ca/)
- [Milk pooling agreements | Canadian Dairy Commission \(cdc-ccl.ca\)](https://cdc-ccl.ca/milk-pooling-agreements)

■ Challenges for Economic Sustainability

All of the above are meant to provide a glimpse into on how the rules of supply management operate and how they contribute to an economic sustainability market in Canadian dairy. But of course, like anything, there are always challenges to sustainability's perennialism. Here we stop to take a look at some key issues that challenge sustainability in the structure of the dairy market:

- Structural surplus of skim milk relative to butterfat.
- Stakeholder initiatives addressing processor-retailer economic relationship (i.e., retail code of conduct).
- Generational change in dairy farming. This includes inter and intra provincial variation in farm management structures, farm debt, purchased feed cost volatility, and labour scarcity.
- Volatility in demand, changing consumer preferences, and tight consumer budgets.

Each of these issues have been raised by the CMSMC membership and are the subject of discussion in various industry fora. With continued cooperation between stakeholders in Canada, including continued coordination at the CMSMC, the rules and organizations of supply management will continue to pursue economic sustainability in the sector.

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Sustainable Canadian Dairy: Why it is Important and How it is Being Achieved

Connie McLellan

Dairy Lead-National Sustainability Team, Ducks Unlimited Canada, 251 rang St-Croix, St-Raymond, QC, G3L 3H4. Email: c_mclellan@ducks.ca

■ Take Home Messages

- Implementing practices and infrastructure that increase farm sustainability is necessary in today's ever-changing climate and price market.
- Canadian dairy farmers need to tell their story to consumers about all the great things they do to protect and enhance our land.
- We hear a lot about methane reduction. Methane has a much shorter life in the atmosphere than carbon but is much more potent, which is why methane reduction is important.
- Cattle create methane through enteric fermentation of food digestion, part of the natural process called the biogenic carbon cycle. This cycle sees plants sequester carbon from the atmosphere and turn it into plant cellulose. The plant is in turn eaten by the cow, the byproduct of digestion exits the cow as methane, and then the methane is broken down in the atmosphere over 10 to 12 years and returned to the plant in the form of carbon.
- Methane emissions can be effectively reduced through genetic selection, feed additives and manure storage and application.
- Fossil fuels are not part of the biogenic carbon cycle and take thousands of years to break down in the atmosphere. Reduction of methane will decrease emissions, while reduction of carbon will plateau emissions because of the differing atmospheric life spans.
- In April 2023 Canada became the first country to offer methane efficiency values in genetic evaluations. Selecting bulls for feed and methane efficiency can effectively reduce emissions.
- When investing in new infrastructure or equipment, dairy farmers must make informed choices about energy efficient and water reducing products and technologies.
- Land based sustainable practices can have big positive effects, not only on greenhouse gas emissions but also on protecting the land against weather extremes and enhancing the land for the future without increasing inputs or sacrificing outputs.
- Sustainable practices can protect soil against erosion, decrease compaction, increase nutrient and organic matter, increase water holding capacity and store carbon.
- Management of wetlands and riparian areas can protect land against flooding and drought and provide important habitat.
- Stopping land conversion protects habitats for wildlife and pollinators that are integral for food production through plant pollination. Trees sequester carbon and protect land against wind erosion and extreme weather.
- Canadian dairy farmers are stewards of the land who need to protect and enhance the land for a sustainable dairy future.

■ Introduction

What is the definition of sustainability? Sustainability is the ability to persist continuously overtime. Canadian dairy farmers are a prime example of sustainability, with the majority being 3rd generation or more. Properly caring for soil, water, and habitat, plus making sustainable herd and infrastructure choices, ensures a healthy farm that can continue to be passed down through the generations. The importance of implementing sustainable practices on Canadian dairy farms has become ever more increasingly evident. As extreme weather patterns become more frequent and land-based challenges continue to increase, finding ways to safeguard agricultural land against these changes is necessary. Increasing sustainability is not only important for protecting land, but also for ensuring a positive public image. In a public survey, Canadian dairy farmers were found to be as trusted as doctors; that's an image we want to preserve and protect. The sustainable practices that farmers have been carrying out for years have always been their best kept secret, but this is changing because consumers are ever increasingly aware and curious about how their food is made. Producers need to let the public in on all the great things they are doing and have been doing for years. They need to define themselves, not be defined by others.

When we hear the word sustainability often we think of the land. While land management and cropping practices are a big part of being sustainable, there are also other factors that contribute. Herd management plays a big role in dairy sustainability; making informed decisions about breeding, culling, replacement animals and herd health practices can increase farm sustainability. Infrastructure choices also can be pertinent in increased sustainability through decreased energy use and cost, improved animal comfort leading to longer life spans, and efficient manure management that decreases methane emissions and improves overall efficiency.

■ Carbon versus Methane

We hear a lot about carbon and methane. There is a large push for the dairy industry to reduce methane emissions. Methane is 28% more potent than carbon dioxide for trapping heat in the atmosphere but has a shorter lifespan (United States Environmental Protection Agency, 2023). Methane has a life span of about 12 years in the atmosphere; carbon dioxide can last hundreds of years.

Methane levels have more than doubled over the last 200 years, coming from both natural and manmade sources, with man-made making up about 60% of today's atmospheric carbon (NASA, 2023). Methane is naturally destroyed by biological and chemical processes. This can happen by a reaction with atmospheric hydroxyl and chlorine or by bacteria that consume methane in soil and water (Nisbet-Jones et al., 2021). The potency and lifespan of methane versus carbon is one of the main reasons for a greater push on lowering methane emissions rather than carbon emissions. Reducing methane emissions will reduce warming, whereas reducing carbon emissions will just result in a plateau of warming (Figure 1, Allen et al., 2022).

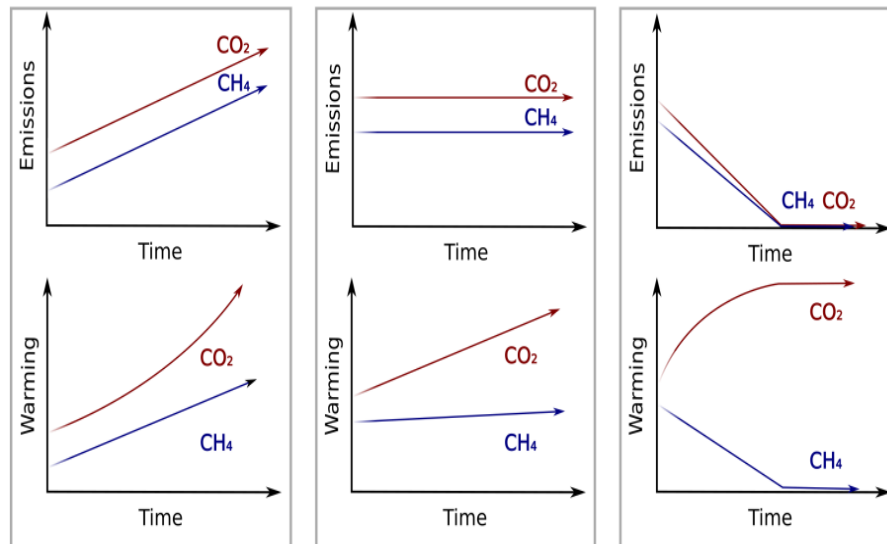


Figure 1. Reduction of carbon versus methane (Allen et al., 2022)

Ruminant animals create methane through enteric fermentation in the rumen and through the anaerobic decomposition of their manure. Even though ruminant methane production and breakdown are part of the natural carbon cycle, methane's potency in the atmosphere makes methane a large contributor to global warming.

▪ Biogenic Carbon Cycle

Methane created by cattle is part of an important natural cycle called the biogenic carbon cycle (Figure 2). This cycle centres around plant photosynthesis and the plant's ability to take carbon from the atmosphere and turn it into oxygen. When plants photosynthesize, a large percentage of the carbon is converted into cellulose. Two thirds of the world's agricultural lands are marginal lands that are not good for growing high input crops but can grow cellulose-dense grasses that are not edible for humans but highly edible for cattle. Cattle digest the carbon in plants and turn it into energy for growth, milk production and other metabolic processes. The methane that cows emit is a by-product of the plant carbon; this returns the carbon that had been sequestered by the plants back to the atmosphere. Methane emitted by cattle is not a new gas emission into the atmosphere, but a gas that had already been there, just transformed into a new element. After 10 to 12 years the methane emitted by the cow is converted back into carbon dioxide, which can then again be sequestered by plants, completing the biogenic carbon cycle (Werth, 2020).

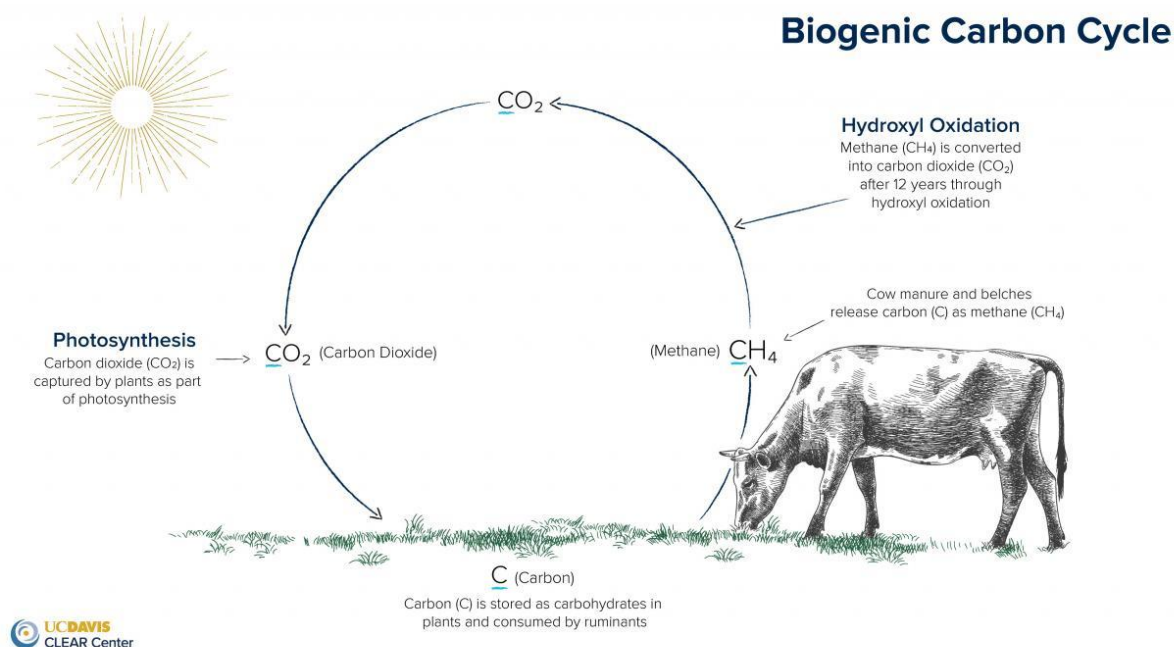


Figure 2. Biogenic carbon cycle (Werth, 2020)

Fossil fuels are not part of the biogenic carbon cycle. Burning fossil fuels has a much greater impact on the atmosphere because the carbon exchange between the atmosphere and geological reserves (deep ocean, rocks, deep soil) takes thousands of years. The biogenic carbon cycle is quite fast, taking a few years to a few decades between plants and the atmosphere and about ten years between cattle and the atmosphere. Therefore, the thousands of years it takes to return carbon dioxide from burning fossil fuels back into geological reserves is ten-fold the amount of time methane belched by cattle takes to return to plants. The carbon dioxide released while driving a car will last in the atmosphere longer than the lifetime of our grandchildren, creating a much more longstanding impact on our climate than does the methane emitted from cattle (Werth, 2020).

■ How and Why Sustainable Practices can be Easily Implemented

As previously mentioned, Canadian dairy farmers are already incorporating sustainable practices in their farm management. As weather patterns change and profit margins decrease, producers have no choice but to find the most effective ways to produce milk.

In April 2023, Canada became the first country to publish methane efficiency in genetic evaluations. Selecting for the methane efficiency gene can reduce methane emissions by 20-30% per year and has no negative effects on milk production and a slight positive correlation with health and fertility and metabolic disease resistance. Canadian dairy farmers are also offered the feed efficiency trait in genetic evaluations. Using this, in conjunction with the methane reduction gene when choosing sires, can help contribute to environmental sustainability and cost efficiency within a herd. It is a fairly easy, yet effective way to decrease methane emissions (Sweett and Van Doormaal, 2023).

Infrastructure choices are another way to reduce emissions and costs on farm. When investing in new equipment, barns, technology, etc., producers should become informed of the choices that will increase on-farm sustainability. Incorporating systems to reduce water use or recycle water, and lowering energy use through solar panels, wind energy and efficient lighting can all have positive effects, not only on emissions, but also on the farm's bottom line. Proper manure storage and handling can have enormous effects on

decreasing methane emissions. Some investments, such as biodigesters, covered manure storage and injection equipment, while very efficient at emissions reductions, can be very costly. There are ways to decrease methane emissions on farm without a large investment through decreased storage time and proper nutrient management (Dairy Farmers of Canada, 2023)

Land-based practices are also a big way to have a positive impact on the environment without large investment (Figure 3). Besides lowering emissions, implementing sustainable land management programs can safeguard the farm against changing weather patterns and decrease inputs and increase outputs, thus increasing profit and ensuring a prosperous future for the farm. There are many practices that producers may already incorporate into their farm management or could easily be added. Examples include reduced tillage, using cover crops, managing nutrients properly, growing more forage and perennials, using rotational grazing, protecting wetlands and riparian areas, and protecting forest and habitat by decreased land conversion. These practices can have large positive impacts not only on the environment as a whole, but at the farm level. Implementing practices such as the ones listed above while show positive impacts in three main categories: soil, water, and biodiversity. Let's take a closer look at why these three things are so important to the future of individual farms and the Canadian dairy industry.

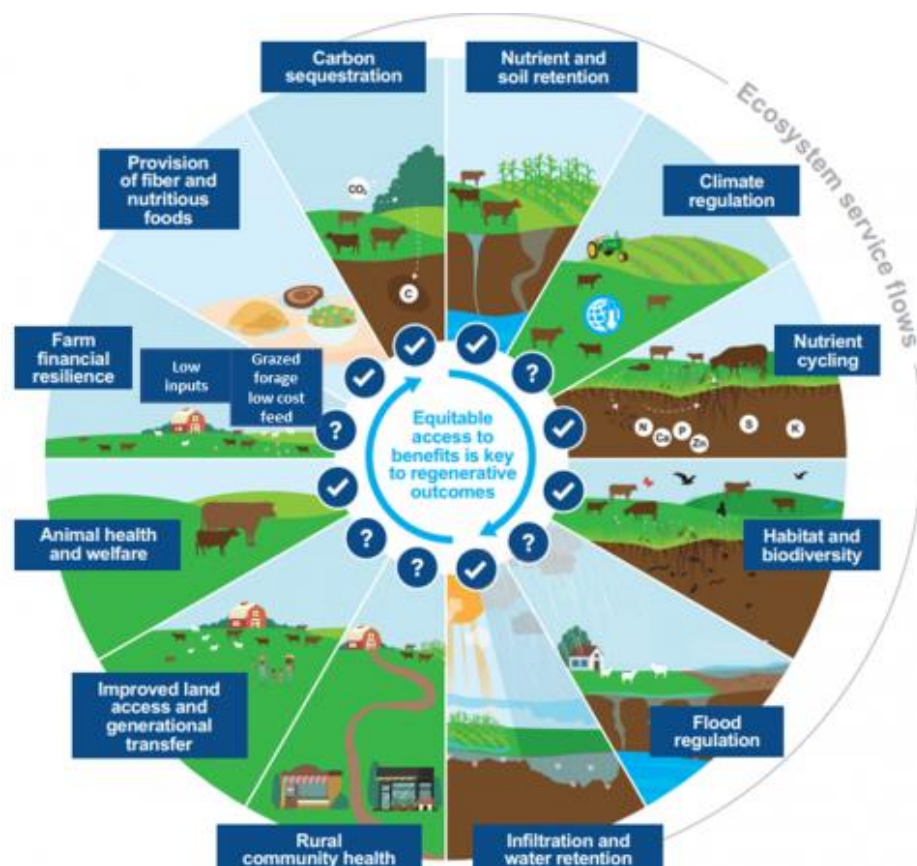


Figure 3. A healthy ecosystem (Cutress, 2021)

■ Soil

Healthy soil is imperative for a profitable farm. Using sustainable practices to enhance soil health can improve soil to the point that less costly inputs are needed, thus saving the farmer time and money while continuing to have profitable yields. We know that the soil is a living thing, full of bacteria, fungi, and insects that help keep the soil healthy for our use, so in turn we must protect them. Reduced tillage not only lowers greenhouse gas emissions but also reduces compaction, which allows water to better filtrate the soil and plant roots to spread more easily and deeper. Reduced tillage or cover crops also protects soil against wind

and water erosion, increases soil organic matter, and improves water retention capacity of the soil. Planting more perennial plants not only provides habitat for pollinator species which are integral to the yield of crops but ensures a constant root structure in the soil to decrease compaction and fight erosion while sequestering carbon. Proper crop rotation and the planting of legumes also aid in soil health by not depleting the soil of a certain nutrient in high demand by a particular crop. Why are these benefits so important? With the ever-increasing frequency of extreme weather, having healthy soil can save crops. During a drought healthy uncompacted soil can hold more water and roots can travel deeper to access that water. If flooding occurs, a healthy soil has a great water holding capacity and stronger soil aggregates to decrease the amount of topsoil lost. The same principles apply to soil with constant vegetative cover versus being barren. Fields with cover crops are more productive than those without; in addition to the above-mentioned benefits, they also promote mycorrhizal growth, suppress weeds, and minimize soil evaporation. Costs for synthetic fertilizer, sprays and diesel continue to increase; having a soil high in organic matter and use of green fertilizers can reduce these input costs. Everything works as a cycle, starting with soil. Healthy bacteria and fungi create healthy soil, creating healthy plants, creating healthy animals and pollinators, and creating high quality products for our consumption.

■ **Water**

Water is great, until there is too little or too much. Water quantity and quality are becoming more popular topics in farming as drought and flooding events increase and water quality decreases. Protecting water that naturally occurs on the landscape is an important factor in protecting agricultural land for the future. Protecting or enhancing naturally occurring wet areas or wetlands can greatly reduce flood effects and these areas can be used as a water source for crop irrigation or cattle watering during droughts. If the area is too wet to be used for cropping, it is better served as a constructed wetland for water control. When there is not a naturally occurring wetland but there are issues with flooding, a wetland could be created to help deal with the problem. Capturing and storing water will become crucial for sustainable agriculture. Rainwater, runoff or even treated wastewater can be stored and later used for irrigation. The creation of riparian areas and buffer zones around water ways on agricultural land increases water quality through decreased runoff by trapping excessive nutrients and sediments and creates wildlife habitat. Efficient water use in agriculture must continue to increase in the future, not only in cropping, but in the barn as well with adaptations to milking and washing systems to reduce water use or recycle water.

■ **Biodiversity**

Biodiversity is a newer, but ever-growing topic in agriculture. It refers to all living organisms in an area. Biodiversity makes the earth liveable, from filtering air we breathe and water we drink, to regenerating soil and providing pollination for crops and plants, which in turn creates a food chain from which we eat. Other important aspects also include fungi, which are used in medicine, and animals, which keep disease vectors, like ticks, in check. Protecting and enhancing biodiversity has a compounding positive effect on agricultural land. A goal not only the Canadian dairy industry should be striving for, but all sectors of agriculture, is to stop land conversion. By implementing the above-mentioned practices, we can make existing agricultural soils more productive and increase yields without bringing more land into production. Keeping intact grasslands, forests and other habitats is pertinent to the protection and future of our planet. Intact habitat, tree lines, rock piles, buffer strips, etc., not only sequester carbon and provide a home and nourishment for thousands of different species, but they also protect and enhance our agricultural land by acting as windbreaks, water control, pollination sources, increased soil organic matter and much more. Keeping buffer strips, tree rows or 'unfarmed' areas around fields also decreases pest and crop disease instances. Farms with high levels of biodiversity benefit from healthier soils requiring less inputs, higher yields through increased pollination, higher quality soil through organic matter levels and decreased erosion, lower input costs, decreased pests and disease, increased water control and quality, and long-term soil sustainability.

Canadian dairy farmers must continue to put sustainability at the forefront of their operations to decrease costs while increasing yields, to protect and enhance the land and biodiversity, all to guarantee a great farming future for the next generations.

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Sustainability and On-Farm Realities: Our Journey

Annie AcMoody

Dairy Farmers of Canada, Ottawa, Ontario, Canada, K1P 1A4. Email: Annie.Acmoody@dfc-plc.ca

▪ Take Home Messages

- Canadian consumers are placing increased importance on sustainable food production and the dairy industry meeting Canada's net zero by 2050 target.
- Canadian dairy farmers are leaders in sustainability and have one of the lowest carbon footprints in the world.
- Increased on-farm efficiencies can lead to greater sustainability.
- Sustainability must make economic sense to dairy farmers.
- Dairy Farmers of Canada's net zero strategy aims to mitigate the impacts of climate change, ensure a thriving dairy industry, respond to consumer expectations, and align with outside targets.

▪ Sustainability is Important to Canadian Consumers

In 2021, Dairy Farmers of Canada (DFC) worked with a consultant to conduct an online representative survey of 1,051 Canadians who were 18 years of age or older. The research gauged the opinions among participants on dairy farming, impressions of farming practices, and importance of meeting environmental targets. One of the key findings demonstrated that roughly eight in 10 Canadians feel it is necessary or somewhat necessary for Canada's dairy farms to achieve Canada's net zero 2050 target. This is up from 71% the year prior. The output from these assessments was a priority matrix, shown in Figure 1, which identified the priority environmental variables of highest importance to both consumers and the industry.

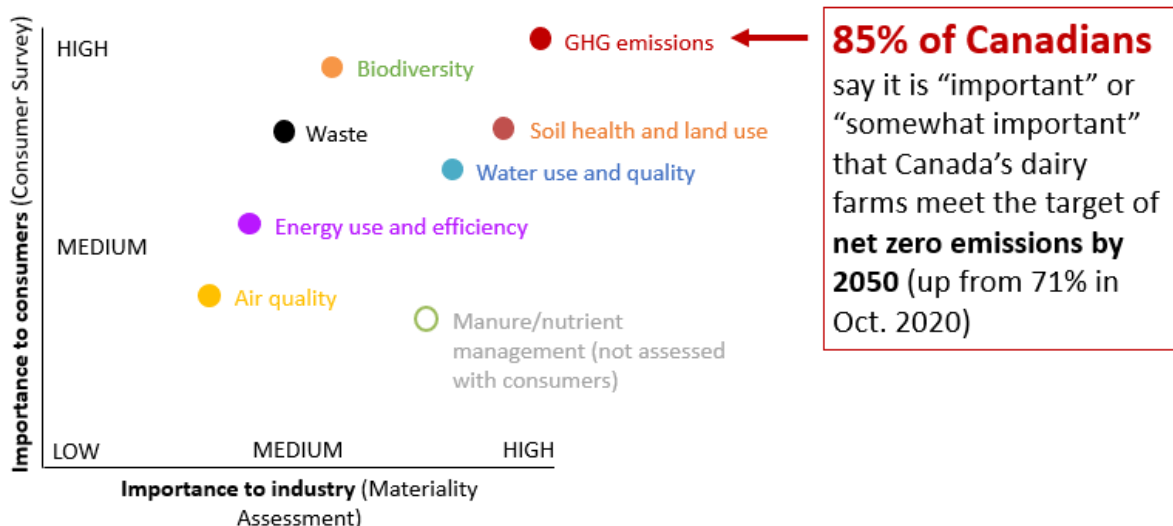


Figure 1. Priority Matrix of environmental issues developed by DFC, based on the September 2021 Consumer Survey and 2021 Materiality Assessment (Viresco Solutions. 2022. *Dairy Farmers of Canada Environmental Sustainability Strategy Draft*).

Environmental sustainability ranks higher with our consumer base than ever before, and as the market changes, with millennials and Generation Z becoming heads of their households, this trend will continue. It is evident it is happening across all sectors, with many businesses also announcing their sustainability strategies. DFC understands it is important to show everyone on the dairy value chain, from our partners to our consumers, that Canada's dairy farmers share their concern for the environment. When decisions are being made at the grocery store, DFC wants consumers to continue reaching for dairy products made with 100% Canadian milk because consumers' values are DFC's values, too.

▪ Setting a Net Zero by 2050 Target

On February 2, 2022, DFC unveiled a goal to reach net-zero greenhouse gas (GHG) emissions from farm-level dairy production by the year 2050. This commitment is aligned with the Government of Canada's goal of net-zero GHG emissions by 2050.

Our net zero strategy is a continuation of the ongoing efforts by the dairy industry related to environmental stewardship, as Canadian dairy farmers are already leaders in sustainability with a carbon footprint per litre of milk produced among the lowest in the world. This tangible and ambitious objective demonstrates that our farmers are sensitive to environmental concerns and want to continue to lead the way.

Viresco Solutions, a firm of Canada's leading consultants in low carbon and sustainable agriculture, was contracted to assess pathways to address these areas. Dairy farmers from across Canada participated in focus groups to provide input on the variety of suggested pathways. Based on this input, extensive research, and consultation with experts, Viresco Solutions modelled a net zero by 2050 scenario with various best management practices (BMP, Figure 2). DFC's Board of Directors voted to approve an objective to be net zero by 2050.

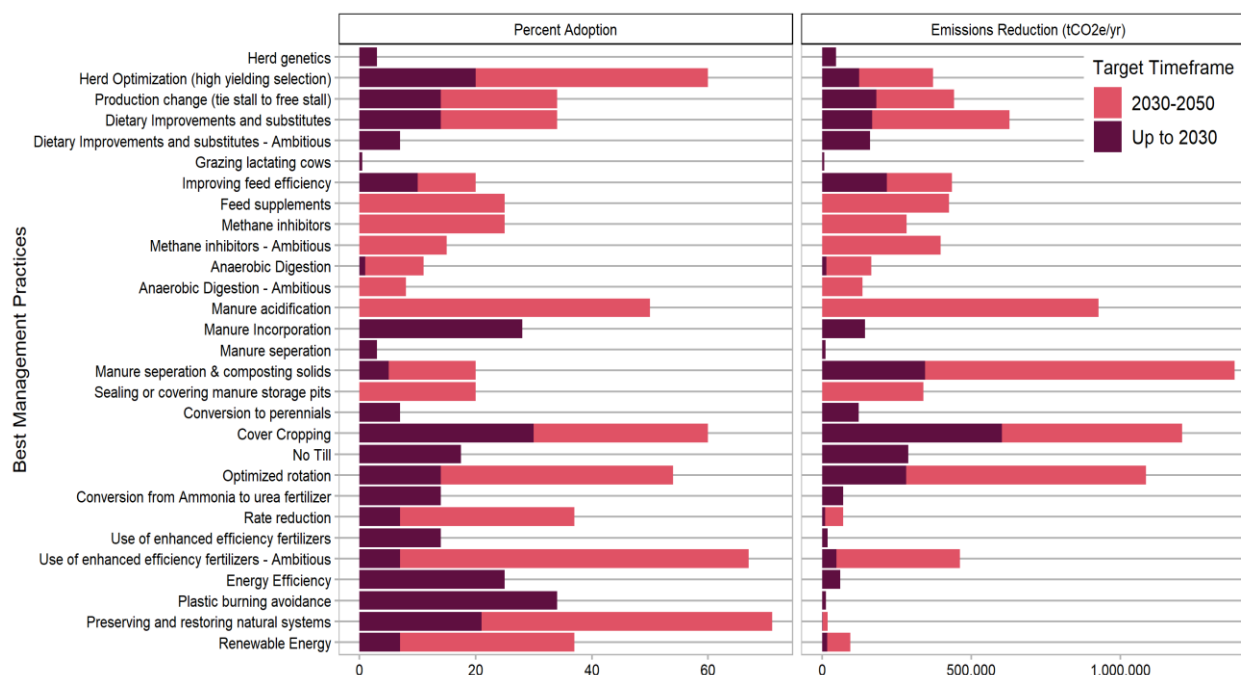


Figure 2. Increased Adoption and associated emissions reductions from different BMP for the Net Zero Targets (Viresco Solutions, 2022. Dairy Farmers of Canada Environmental Sustainability Strategy Draft).

■ DFC's Net Zero Strategy and the Best Management Practices Guide

DFC released its *Net Zero by 2050 Best Management Practices Guide to Mitigate Emissions on Dairy Farms* in March 2023 (Figure 3). The guide helps Canadian dairy farmers contribute to reaching net-zero GHG emissions by 2050. Working toward this target confirms that the dairy sector is part of our country's solutions to tackle climate change and ensures that consumers can continue enjoying dairy products made with 100% Canadian milk for years to come.

DFC's *Best Practices Guide* has been developed in consultation with experts to help farmers identify and implement BMP on their farm, including an overview of 30 on-farm practices supported by current research that outline opportunities for reducing emissions, increasing carbon sequestration, and improving overall environmental sustainability. In general, increased on-farm efficiencies contribute to overall sustainability.

The BMP are organized according to the four categories in DFC's Life Cycle Assessment: Livestock Management, Feed Management, Manure Management, and Energy, Infrastructure and Transportation, along with a fifth category for Land Management, which includes practices aimed at carbon sequestration and biodiversity enhancement. Each BMP highlights the benefits associated with each practice, tips for implementation, and resources for additional information.



Figure 3. Best Management Practices Guide preview

([https://dairyfarmersofcanada.ca/sites/default/files/2023-07/DFC BMP%20Guide 2023-07-05.pdf](https://dairyfarmersofcanada.ca/sites/default/files/2023-07/DFC_BMP%20Guide_2023-07-05.pdf)).

The sustainability strategy may be supported by, but is separate from proAction®, DFC's national quality assurance program, which is mandatory on all dairy farms. To achieve the sustainability objectives, farmers can voluntarily choose how to adopt sustainability practices based on the uniqueness of their farm. Together, we will collectively move the dial on sustainability at the national level.

Many of the practices identified in the BMP Guide that reduce emissions have co-benefits that contribute

to the health of local ecosystems, increase the use of renewable energy, and recycle more plastics. These are all important components of environmental sustainability and help increase farms' resilience to the effects of climate change. Our strategy addresses five priority areas, identified in Figure 4.



Figure 4. Identified priority areas in DFC's sustainability strategy
(https://dairyfarmersofcanada.ca/sites/default/files/2023-03/DFC_Net-Zero%20Strategy_FINAL_WEB.pdf).

As part of our overall strategy, DFC also published *Dairy Farming Forward to 2050* in March 2023, which outlines the strategic approaches to help guide the pathway toward achieving net zero (Figure 5). DFC is committed to supporting farmers to advance sustainability and efficiency of their operations by developing strategic partnerships with leading environmental organizations; increasing research, innovation, and knowledge and technology transfer; ensuring farmers are supported by beneficial regulatory environments and markets; leveraging economic opportunities; and communicating on farmers' sustainability journeys. DFC will soon be completing our 2021 life cycle assessment, which includes a new biodiversity assessment and is supplemented by a coordinating carbon sequestration study. These initiatives will inform our strategy and collaboration with diverse stakeholders to support dairy farmers' continuous sustainability efforts.

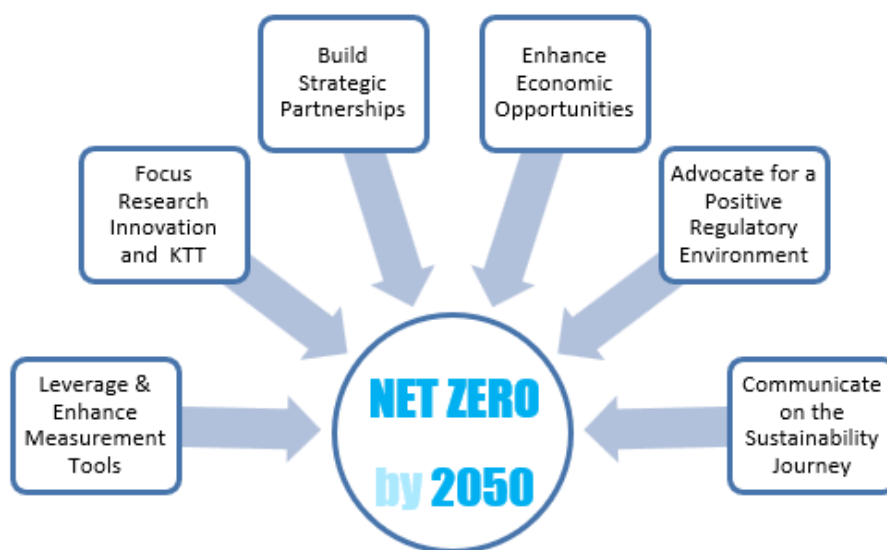


Figure 5. DFC's strategic approaches to support farmers, as well as streamline efforts across industry. (https://dairyfarmersofcanada.ca/sites/default/files/2023-03/DFC_Net-Zero%20Strategy_FINAL_WEB.pdf).

■ Ongoing Initiatives

DFC continues to advance our sustainability strategy and find new ways to support farmers to adopt BMP. We understand that every dairy farm is unique, and that means different strategies will work for different operations, which will require a variety of tools to contribute to our sector's ongoing success.

DFC is working with GHG reduction specialists, federal and provincial governments, dairy stakeholders, and most importantly, farmers, on strategies that can be applied at the farm level to reduce and sequester emissions as we strive for continuous improvement (Figure 6).



Figure 6. DFC's partnerships to help drive BMP uptake. Organizations like Cleanfarms, Tree Canada, Ducks Unlimited Canada, and Alus can make it easier to recycle plastic, protect waterways, and promote biodiversity (<https://dairyfarmersofcanada.ca/en/sustainability/our-partners-sustainability>).

One of the main overarching challenges we face is ensuring the adoption of BMP make economic sense for farmers. Some of our initiatives targeting economic opportunities include an assessment of existing and missing financial incentives to support dairy farmers in adoption of specific BMP with low adoption rates, little return on investment and high GHG mitigation potential. The final report is complete and will inform DFC's advocacy efforts to help increase relevant financial incentives for Canadian dairy farmers.

We are also developing a handout for farmers that outlines opportunities, challenges and considerations related to carbon offsets and insets. We understand financial incentives must go beyond initial implementation costs and account for potential impact on yield, maintenance costs and more to make sure farmers are recognized for doing their part.

To ensure progress is measured, DFC will be updating the net-zero modelling with new data from the 2021 life cycle assessment once available. Additionally, we are developing an on-farm GHG calculator to support farmers with their sustainability efforts and continuous improvement plans. A benchmarking project is also underway, which will benchmark proAction to other sustainability programs and create a framework for reporting against future programs.

We continue to develop strategic partnerships to support dairy farmers with adoption of BMP. Through our partnership with Farm Credit Canada, dairy farmers who are Farm Credit Canada customers and meet sustainability requirements can access an incentive payment of up to \$2,000 through the Sustainability Incentive Program. DFC also supported Lactanet and Semex who were recognized in October 2023 during the International Dairy Federation World Dairy Summit for developing Canada's Methane Efficiency genetic evaluation. This is the world's first official genetic evaluation that helps dairy farmers genetically select animals that will contribute to reduced methane emissions from dairy cattle, without impacting production levels.

Knowledge translation and transfer are also critical parts of our strategy and support the research continuum for sector growth. Ensuring sufficient and effective on-farm knowledge transfer to encourage farmers to implement BMP that make sense for their operations and demonstrate the research behind the on-farm impacts is at the core of how we implement our sustainability initiatives. DFC has a two-pronged approach to knowledge translation and transfer: 1) communicating the results of individual research projects and 2) communicating the overall results from a broader body of research to support science-based BMP adoption.

DFC has a National Dairy Research Strategy and one of the three areas of focus is dairy farm sustainability. DFC reports on dairy sustainability research investments, implements effective means of translating and transferring results to support dairy farmers' efforts to continuously improve their practices, and communicates findings on the role of dairy products in a healthy and sustainable Canadian diet.

■ Where We are Headed

While excellent progress has been made and continues to be made by dairy farmers, many challenges exist that escalate the financial pressures dairy farmers face and limit their ability to tackle evolving economic, social, and environmental demands.

These challenges include but are not limited to high inflation, rising costs of inputs and production, market access concessions, cost, shortage of labour, evolving consumer expectations, growing anti-livestock rhetoric, supply chain disruptions, and price of land — all while dairy farmers are often on the frontlines of extreme weather event impacts as a result of climate change.

One of the lessons we've learned while developing our net zero strategy is that we need to support dairy farmers through a comprehensive approach that addresses farms' socio-economic realities. We continue to advocate for the economic, environmental, and social components of sustainability throughout government consultations, strategic partnerships, and most recently at COP28. DFC sent its inaugural delegation to COP, where Korb Whale, a dairy farmer from Alma, Ontario, was a panelist at the Canadian Federation of Agriculture's event on industry-led agriculture sustainability initiatives. Korb spoke about the role of dairy farmers' in helping mitigate the impacts of climate change, sustainability policies supporting a thriving dairy sector, responding to consumer demands while advocating dairy's place in nutrient dense and climate smart diets, and the importance of DFC's net zero strategy aligning with outside targets while streamlining efforts across the industry (Figure 7).



Figure 7. Four key aims of DFC's net zero strategy.

DFC understands intersectional support is needed to allow dairy farmers to continue to fulfil their role as sustainability leaders while also ensuring on-farm profitability, maintaining an innovative and resilient agriculture industry, and contributing to the Government of Canada's efforts to meet their Paris Agreement commitments including achieving our shared net-zero emissions by 2050 target.

■ Resources

Dairy Farmers of Canada. 2023. *Net Zero by 2050 Best Management Practices Guide to Mitigate Emissions on Dairy Farms*. https://dairyfarmersofcanada.ca/sites/default/files/2023-07/DFC_BMP%20Guide_2023-07-05.pdf

Dairy Farmers of Canada. 2023. *Dairy Farming Forward to 2050*. https://dairyfarmersofcanada.ca/sites/default/files/2023-03/DFC_Net-Zero%20Strategy_FINAL_WEB.pdf

Dairy Farmers of Canada. <https://dairyfarmersofcanada.ca/en/sustainability/our-partners-sustainability>

Viresco Solutions. 2022. *Dairy Farmers of Canada Environmental Sustainability Strategy Draft*.



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Feed Preference and Feed Intake: Is there a Real-World Link that NASEM Predictive Models Overlook?

Addison L. Carroll and Paul J. Kononoff

Department of Animal Science, University of Nebraska-Lincoln, Lincoln, NE. Email: pkononoff2@unl.edu

■ Take Home Messages

- Current and historical equations to predict dry matter intake (DMI) have focused on the physiological aspects that influence feed intake.
- Surprisingly there may already be aspects of the current DMI models that consider feed palatability characteristics including forage fragility and the filling effect of feeds.
- There are large opportunities to explore feed palatability, its subsequent positive or negative influence on animal feed preference and DMI, and potential integration into predictive equations for intake.

■ Introduction

During the height of the civil war in 1863 the National Academy of Sciences was established to bring scientific experts together and develop scientific and technical recommendations. After some time, in 1906 chemists and applied nutritionists were locked in a debate of animal feed preference. More specifically, one nutritionist declared that "... the cow knows better than the chemist what she likes to eat, and it is little use to offer her foods she does not relish" (Jordan, 1906), whereas chemists commonly believed that animals lack the cognitive precision needed to select their feed. Research activity in feed preference carried on, but with less emphasis. This may be in part because of the efforts demanded for World War II. This was when the National Academy of Sciences formed committees to undertake and assess research that would be used to develop feeding standards for livestock. These feeding standards were commonly referred to as NRC, and later NASEM, for the National Academy of Science Engineering and Medicine, feeding recommendations. This new focus may have contributed to a shift of attention away from studying feed preference and additional efforts placed into controlled feeding experiments aiming to understand chemical characteristics of feed, digestibility and whole-animal physiological mechanisms that controlled dry matter intake (DMI). We speculate that individual feed preference is an important component of the overall variance observed in feed intake (Carroll et al., 2022). Feed preference is at least in part influenced by the 'palatability factors' including aroma, taste, and physical structure. Feed preference can be defined as the action of choosing and it is influenced by these factors. Preference can be measured in a variety of ways such as 'cafeteria' type experiments where animals can select from a variety of feeds to make a 'diet'. However, in dairy cattle two to four ingredients of interest are generally placed in front of the animal for a fixed period of time. In response, the animal will consume the most 'preferred' feed, and subsequently return to its ration. The objective of this presentation is to highlight NASEM predictions for DMI and to discuss how the concepts of palatability and preference may also affect feed intake.

■ Dry Matter Intake

How does the NASEM predict DMI? The control of DMI within lactating dairy cattle is complex and influenced by both physiological signals and the diet itself, which when combined, affects feeding behaviour and in turn, DMI. In the most recent NASEM publication, DMI is estimated for lactating dairy cows using two different equations:

Eq. 2-1; Page 12:

$$\text{DMI (kg/d)} = [(3.7 + \text{Parity} \times 5.7) + 0.305 \times \text{MilKE (Mcal/d)} + 0.022 \times \text{BW (kg)} + (-0.689 + \text{Parity} \times -1.87) \times \text{BCS}] \times [1 - (0.212 + \text{Parity} \times 0.136) \times e^{(-0.053 \times \text{DIM})}]$$

Eq. 2-2; Page 13:

$$\text{DMI (kg/d)} = 12.0 - 0.107 \times \text{FNDF} + 8.17 \times \text{ADF/NDF} + 0.0253 \times \text{FNDFD} - 0.328 \times (\text{ADF/NDF} - 0.602) \times (\text{FNDFD} - 48.3) + 0.225 \times \text{MY} + 0.00390 \times (\text{FNDFD} - 48.3) \times (\text{MY} - 33.1)$$

The first equation included animal-based factors that affect DMI such as parity, milk energy (MilKE) output, body weight (BW), body condition score, and days in milk (DIM). This equation was similar to that of NRC (2001) that used animal factors to predict DMI. The second equation was new to NASEM (2021) and included dietary factors such as forage neutral detergent fibre (NDF) digestibility (FNDFD), the ratio of acid detergent fibre (ADF) to NDF, and milk yield (MY). These factors were used to represent the filling effect of feed that is thought to limit DMI through distention. While this may be true in animals greater than 60 DIM (Allen et al., 2019), for animals less than 60 DIM, DMI may be more controlled through chemostatic regulation and thus the first equation may be more applicable.

■ Cattle Chemical Senses

Taste: Taste is thought to be the most important sense to affect feed preference (Houpt, 2004). In animals, taste receptor cells are located in taste buds and cattle possess 2-3 times as many taste buds as humans. These taste buds are distributed evenly across both halves of the tongue but are in greater quantity on the first two-thirds and especially dense on the tip (Ginane et al., 2011). Like humans, cattle have the ability to taste five distinct flavours: sweetness, saltiness, bitterness, sourness, and umami also known as savouriness (Myers and Coulter, 2004). The mechanisms for taste receptors are not fully understood; however, there are two families of taste receptors including those that can sense sweet/umami, and those that can sense bitterness. Interestingly, salty and sour are not mediated by receptors but by changes in the ion channels.

Smell: Current research regarding the sense of smell in cattle has predominantly been related to pheromones and the vomeronasal organ. Scents pertaining to feed are processed through odorant receptors within the nasal cavity. Interestingly, normal respiration allows for scent to be processed, but a 'sniffing' action causes the air to more forcefully contact the scent receptors. Unlike taste receptors, odorant receptors are highly variable across species and have been hypothesized to be selective. More specifically, these odorant receptors differ between species in a similar manner to how different species process visual colours (Myers and Coulter, 2004). Thus, it is difficult to extrapolate human experiences of scent to that of cattle. Due to the close nature of an interplay between smell and taste, food consumption can also be mediated by smell. For example, cattle will avoid consuming forage when feces are placed under, but are not touching, the feed source for a period of up to 35 days (Dohi et al., 1991). However, smell is generally a secondary aspect of preference relative to taste.

■ Preference and Palatability

What is feed preference and palatability and the associated role on feed intake Feed preference, in its simplest form, is a choice of one feed item over another. Given that animals have their own volition, it stands to reason that the display preference differs across animals (Galef, 1991). Livestock possess what is described as 'first order preference', while humans possess both 'first and second order preference.' This means that if an animal desires something it will be followed up by a single action whereas humans may desire something but take no action into obtaining it (Jeffrey, 1974). Palatability is defined as feed characteristics or conditions that stimulate a selective response by the animal (Baumont, 1996). Therefore, preference is the action, but palatability is the characteristic(s) that drives that action. One such physiological aspect that influences preference outside of taste includes the cow's organ of prehension, the tongue. The cow's tongue moves across a horizontal plane in order to 'scoop' feed into the mouth (Hudson

and Frank, 1987). Thus, feeds that make this action easier may be more preferred.

■ Preference and DMI

How do DMI and preference overlap? It has been generally believed that a cow's behaviour could direct her to eat to meet her nutritional requirements. Alternatively, it was also argued that animals were non-discerning and would eat to illness, and thus nutritionists needed to formulate diets to meet their nutritional requirements (Jordan, 1906). An example of eating to illness is a cow accessing grain stores, engorging in carbohydrates (starch), and subsequently developing rumen acidosis (Radostits et al., 2007). Aspects of current DMI equations overlap these concepts. One interesting facet of the NASEM 'feed factor' DMI equation (Eq. 2-2 above) is that it accounts for elements related to diet palatability factors that could be linked to animal preference. This facet is the ADF/NDF ratio, which can be influenced by forage type. This ratio is believed to be related to forage fragility and leaf to stem ratio of the forage. Animals generally prefer leaves over stems (Hodgson et al., 2015). In animals on pasture this choice may also reflect the relative ease of grazing because of lower shear strength. Another concept to consider is the filling effect of these feeds; the NASEM equation 2-2 was designed to at least in part represent this concept. Sheep have been observed to avoid alfalfa hay and prefer feeds like beet pulp and wheat bran after their rumens were filled with balloons occupying 1.8 to 4.5 L (Villalba et al., 2009). Thus, ruminal distention may influence an animal's preference for feeds with different filling natures.

■ Preference Factors Not Represented in Equations to Predict DMI

Physical Characteristic of Feeds: Forages Sorting

There are opportunities to use laboratory assays to identify and detect some factors that affect preference of feeds. One of the most simple and well recognized signs of dairy animals showing preference is sorting. Animals will generally sort against longer particle size feeds in favour of those with finer particle size (Onetti et al., 2004), but this is not universal and depends on the nature of the long particle. Animals also generally prefer pellets to meals, partly because of the ability of the tongue to sweep and scoop pellets more easily than meals (Krogstad et al., 2021). This aspect of particle size and feed consumption may have application to AMS systems and the use of pellets. Another management strategy to reduce sorting is through the addition of water (Leonardi et al., 2005). A general recommendation for TMR DM content is from 50–60%; however, guidelines for DM content are not well defined and are likely greatly influenced by the forage type included in a TMR. Decreasing DM content of a dry forage diet from 81% to 64% decreased TMR sorting, but decreasing DM from 58% with no dry forage to below 48% can have an opposing effect and increase sorting activity (Miller-Cushon and DeVries, 2009).

Preservation Methods

Along with particle size, organic acids in silage and inherent plant secondary metabolites can decrease palatability by eliciting a sense of sourness and/or astringency resulting in a mix of both bitter and sour tastes. Organic acids are naturally produced through the ensiling of forages. Previous research with goats has shown that DMI can be reduced with even subtle increases in end products of aerobic grass silage fermentation. These end products include ammonia nitrogen and butyric acid (Gerlach et al., 2014). Feed intake in dairy cattle may also be reduced when silages are exposed to air for a period of time and this is caused by unpalatable end products of aerobic fermentation including silage decomposition spurred by moulds and yeasts. Additionally, a poor fermentation with slow lactic acid build up may influence the amount of butyric acid produced by forages and may reduce DMI (Broderick et al., 2002). It is likely that the pungent aroma of butyric acid plays an important role in feed intake. Although butyric acid is also produced in the rumen it is not known if cows can distinguish between the compound originating from the feed versus that from her digesta. Nonetheless, silage practices that affect fermentation and storage such as face management, compaction, and feeding rate may affect the palatability of silages. Fortunately, many of these factors can be tested analytically or even evaluated through human sight, touch, and smell for quick results. However, caution should be exercised in using human senses to 'test' feeds that may contain harmful organisms and mycotoxins.

Secondary Metabolites

Unpalatable flavours can also be inherent to the plant in either grazing or stored forage systems. Plants produce tannins, saponin, and other compounds to naturally protect themselves from predation and pathogens. Tannins are predominantly found in big trefoil, birds foot trefoil, red clover, and perennial ryegrass, with small quantities in alfalfa (Radostits et al., 2007). They may negatively influence feed preference through characteristics of sourness and bitterness (Shewangzaw, 2016) because relative to sheep and goats, cattle possess lower concentrations of the enzymes that bind tannins prior to the cows tasting them. When tea saponin is mixed into a TMR, cows may refuse to eat; this likely is a function of the bitterness but this may be overcome by pelleting the ingredient (Guyader et al., 2017). Unfortunately, analysis of secondary metabolites is time consuming so targeted analysis should occur when plants of high tannin or saponin concentration are used within the ration.

Sugars, Maillard Products

Cattle possess the ability to sense sweetness, and molasses has long been used to enhance preference. Not only is molasses sweet but it acts as a binder to improve feed palatability. Although not a novel concept, the property of “sweetness” has yet to be integrated into DMI equations. One means of conserving sugar content of forage would be cutting in the afternoon when grass sugar levels are high (Kagan et al., 2011). Sugars may also play a unique role in palatability by interacting and bringing forth a ‘roasted and caramelized’ flavour (Wong et al., 2008). Sugars form complexes with proteins during the heating process resulting in Maillard products. This heating can occur naturally, for example, when alfalfa is baled wet or when byproducts such as distillers grains are dried. For humans, Maillard products are associated with a caramelized taste one gets when consuming foods such as sautéed onions or even toasted bread. Previous research has shown that cattle will consume more corn gluten pellets relative to those containing increased sugar content through the addition of molasses indicating that Maillard products taste may be more palatable relative to sugar’s sweetness (Carroll et al., 2023). Although Maillard products may be preferred over sugars, sugars may be more easily implementable in future intake equations.

Feed Flavouring

Along with the inherent chemical characteristics of feeds, there are opportunities to influence animal preference for feeds with flavouring agents. These flavouring agents can be used both to mask unpleasant flavours and impart more desirable flavours. For example, molasses has been a long-standing ingredient added to improve palatability. However, there are opportunities to use other ingredients as well. By leveraging on umami and salt taste receptors, sheep have been observed to eat more pelleted straw relative to pelleted alfalfa when it was sprayed with monosodium glutamate (MSG) and salt (Grover, 1984). Interestingly both of these are flavouring agents that make food more palatable to humans as well. Spices including fenugreek (Migliorati et al., 2005), oregano, and vanilla improve feed preference (Harper et al., 2016; Carroll et al., 2023). Interestingly, oregano not only seems palatable to cows, but may also mask unpleasant flavours such as bitterness in feeds such as hydrolyzed feather meal. Ultimately there are many flavouring agents available that can impart palatable characteristics in feeds, and opportunities exist to use flavouring agents to mask potentially off-putting flavours that may negatively affect animal intake.

■ Applications and Conclusions

Historically the field of ruminant nutrition has placed emphasis on animal factors in understanding and predicting feed intake. Clearly some feed intake equations already contain aspects related to palatability. Future thought should be given to integrating feed palatability characteristics with equations to predict feed intake. Routine measures such as particle size and sugar content could be implemented in the future equations with greater ease, whereas more time-consuming and costly measures of determining organic acids produced during and after fermentation, secondary metabolites, and Maillard products could be explored to better understand factors that affect feed intake.

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Transitioning to Success: The Intersection Between Peripartum Nutrition, Health, and Reproduction

José Eduardo P. Santos

Department of Animal Sciences, University of Florida, Gainesville, USA. E-mail address: jeptosantos@ufl.edu

■ Take Home Messages

- Manage body condition to avoid excessive body tissue loss in early lactation.
- Minimize the risk of diseases because disease suppresses appetite, causes inflammation and tissue damage, and alters nutrient partition, all of which compromise subsequent performance.
- Stimulate dry matter intake in early lactation by minimizing dietary and management factors that detain cows from eating more.
- Feed diets during the transition period that reduce the risk of diseases.
- Incorporate feed ingredients that have shown benefits to improved pregnancy per artificial insemination.

■ Introduction

The success of a new lactation is largely determined by the events that take place during the last weeks of gestation and the first weeks of lactation. Extensive epidemiological studies clearly show that dairy cows are most susceptible to diseases in the first month or two of lactation. In part, this is simple to understand because the onset of lactation is linked with calving and increased susceptibility of the reproductive tract to problems such as retained placenta and metritis. Also, as lactation starts, the demands for nutrients increase substantially and cows have not been selected to display voracious appetite in the first weeks postpartum. Thus, cows quickly mobilize large amounts of body tissues, and body weight loss often surpasses 40 to 50 kg in the first month postpartum. Some of that weight loss is due to changes in gut fill, but tissue loss is represented primarily by adipose tissue. Cows carrying more body condition at calving are prone to increased tissue mobilization concurrently with reduced appetite. Managing body condition in the preceding lactation is key to minimizing losses in the subsequent lactation. A common denominator among all diseases that affect dairy cows is an inflammatory response. Inflammation is hypophagic (reduces feed intake) and alters nutrient partitioning toward fighting infection and combating inflammation and away from productive functions. The net result is reduced dry matter intake, increased risk of diseases, and compromised production, reproduction, and survival. Managing and feeding dairy cows to minimize the risk of diseases in early lactation is pivotal to the success in the remainder of that lactation. For instance, induction of mild inflammation of the reproductive tract disrupts ovarian and endometrial function, compromises oocyte quality and embryo development, and impairs the ability of the cow to establish and maintain pregnancy. The impacts of disease on fertility extend beyond the period of tissue damage and epidemiological studies show that pregnancy survival is compromised up to five months after the disease is diagnosed and treated. It is increasingly evident that minimizing disease incidence remains one of the foremost aspects of transition cow management.

■ Time in the Transition Group and Risk of Diseases in Early Lactation

Diseases are common in early lactation and are often associated with bacterial infections or with tissue trauma induced by calving. Approximately 30 to 40% of dairy cows are diagnosed with a clinical disease event in the first three to eight weeks of lactation (Santos et al., 2010; Ribeiro et al., 2016), and 75% of the

first clinical disease diagnosis typically happens in the first three weeks postpartum. Diseases in early lactation are more costly because they have the remainder of the lactation to disturb. A case of mastitis at 20 days postpartum is more costly than a similar case at 200 days postpartum.

Transition programs should be designed to reduce the risk of diseases, but cows need time to benefit from what is offered in the prepartum group. Epidemiological studies support the concept that cows should remain three to four weeks in the prepartum group. Vieira-Neto et al. (2021) showed a quadratic association between days in the prepartum group and subsequent risk of morbidity, production, and reproduction in dairy cows. Cows that spent three to four weeks in the prepartum group had the least risk of morbidity, produced the most milk, and had the greatest pregnancy rate.

▪ The Common Underlying Aspects of Diseases

It is easy to understand why cows that suffer from clinical disease have impaired production and reproduction, although the exact cellular mechanisms are not always understood. For instance, being pregnant during nutrient deprivation increases the risk of death in beef cows (Fordyce et al., 1990). Thus, it is not surprising that mechanisms are in place to control reproduction when the supply of nutrients is scarce, and one of the factors that alter nutrient intake and use of nutrients by tissues is disease.

In all species studied, a consequence of disease is suppression of appetite. The exact reason why intake is depressed is not fully understood, but it might be linked with control of nutrients needed for pathogens to thrive during infection or a method to limit nutrients needed for the inflammatory response typically associated with activation of the immune system by trauma or infection (Brown and Bradford, 2021). In addition, diseases often alter how nutrients are used, and the change in partition of nutrients affects the supply of substrate for milk synthesis. For instance, an acute activation of the immune system by lipopolysaccharides or LPS results in hypoglycemia (Kvidera et al., 2017). Replenishing the plasma glucose pool by infusing glucose intravenously was suggested to be a method to quantify the glucose needs for activation of the immune system. Under that scenario, the authors showed that acute activation of the immune system by LPS required almost 1 kg of glucose infused intravenously to maintain plasma glucose concentrations like those of cows treated with sterile saline (Kvidera et al., 2017).

Beef steers subjected to endotracheal bacterial challenge showed a major shift in nutrient use by the splanchnic tissues (Burciaga-Robles, 2009). The authors infused either saline or a solution containing *Mannheimia haemolytica*, a bacterium often associated with bovine respiratory disease. Beef steers were surgically multi-catheterized with catheters placed in the portal vein, hepatic vein, and mesenteric vein and artery to study nutrient flux across the portal-drained viscera and liver after bacterial-induced inflammation of the lungs. They showed that inducing inflammation largely increased the use of nutrients by the liver. Use of essential and non-essential amino acids by the liver increased substantially when steers received the bacterial inoculum. Such effects would increase the calculated nutrient needs for maintenance of the animal.

In dairy cows, inducing mild endometrial inflammation at 37 days postpartum reduced dry matter intake and milk yield and compromised pregnancy rate for the remainder of the lactation (Husnain et al., 2023a). Induced endometrial inflammation at 26 days postpartum impaired conceptus development in lactating cows receiving insemination and a similar treatment to dairy heifers receiving embryos reduced conceptus quality after embryo transfer (Husnain et al., 2023b). Obviously, when cows develop diseases, often they also have fever, and hyperthermia is a known disruptor of pregnancy in cattle. Furthermore, diseases damage tissue and alter their function, which affects numerous aspects of reproduction in dairy cows (Ribeiro et al., 2016). Collectively, the combined effects of disease on tissue integrity and function, release of pro-inflammatory molecules, altered nutrient partitioning, hyperthermia, and exacerbation of negative nutrient balance work in conjunction affecting subsequent production and reproduction in dairy cows.

▪ **Manage Body Condition and Stimulate Dry Matter Intake**

The degree of fatness of cows at dry off or when entering the prepartum group is one of the factors that influence tissue loss in early lactation. Cows with increased body condition in the dry period are those more likely to have extensive lipomobilization in early lactation. It is a simple concept that carries intricate cellular mechanisms. To lose body fat, a cow must carry body fat. Large epidemiological studies have clearly shown that over-conditioned cows are less likely to maintain dry matter intake prepartum, more likely to experience extensive loss of body condition, and more likely to develop postpartum diseases (Roche et al., 2013).

Over-conditioned cows have less appetite and consume less dry matter per unit of body weight than cows in moderate to low body condition. One possibility is that lipomobilization, which is more extensive in over-conditioned cows, induces satiety by increasing hepatic signals that suppress appetite (Allen and Bradford, 2012). Those effects might be more marked in cows fed diets with excess of rumen-fermentable energy in early lactation (Allen and Bradford, 2012). Obviously, cows that mobilize more body tissue are less likely to resume postpartum ovulation before the end of the voluntary waiting period and they also have reduced pregnancy per artificial insemination (AI) and increased risk of pregnancy loss (Santos et al., 2010). Thus, managing body condition in the preceding lactation, by proper feeding according to production, grouping of cows, and having cows become pregnant at the proper time postpartum, will have consequences to the success of the subsequent lactation, in particular reproduction (Fricke et al., 2022).

▪ **Feed Diets to Transition Cows that Reduce the Risk of Diseases**

An important goal of transition cow diets is to reduce the risk of diseases. Meeting the energy needs and avoiding body fat gain in prepartum cows is one of the components of prepartum diets (Drackley and Cardoso, 2014). Supplying sufficient forage neutral detergent fiber (NDF), particularly from sources that maintain physical effectiveness in stimulating cud chewing and rumen fill, reduces the risk of displaced abomasum in early lactation.

Dairy cows are highly susceptible to developing fatty liver in the first weeks of lactation. Excessive accumulation of hepatic triacylglycerol (fat) is linked with suppressed health and production performance in dairy cows (Arshad and Santos, 2022). Prepartum over-conditioned cows are more likely to develop fatty liver in early lactation. Thus, managing body condition and feeding diets that limit lipomobilization reduce fatty liver. Furthermore, certain dietary nutrients can affect fatty liver in cows under negative nutrient balance (Arshad et al., 2023). Choline is supplemented to diets of transition cows because of its benefits to production and health (Arshad et al., 2020). Feeding rumen-protected choline reduced hepatic triacylglycerol accumulation by stimulating hepatic lipoprotein secretion prepartum. When fed during the entire transition period, rumen-protected choline reduces the risk of some diseases and increases yields of energy-corrected milk.

Similar to preventing lipid-related disorders, prevention of mineral related disorders is one of the cornerstones of transition cow diets. Hypocalcemia is a common problem in early postpartum parous dairy cows. Cows with clinical hypocalcemia, also known as milk fever, have numerous problems, and those with persistent subclinical hypocalcemia have reduced dry matter intake, impaired immune response, and increased risk of uterine diseases. One method to reduce hypocalcemia is to alter the mineral composition of the prepartum diet by limiting the intake of sodium, potassium, and phosphorus, and increasing the intake of chloride and magnesium. Such diets affect the acid-base status of prepartum cows, reduce prepartum blood phosphate, and increase the supply of magnesium, which make cows less susceptible to both clinical and subclinical hypocalcemia (Santos et al., 2019). Feeding acidogenic diets prepartum not only reduced the risk of hypocalcemia, but also those of retained placenta and metritis. Parous cows fed acidogenic diets prepartum had increased yields of milk and fat-corrected milk in the subsequent lactation (Santos et al., 2019).

▪ Meet the Nutrient Needs of the Cow

Prepartum diets should meet the nutrient needs of the prepartum cow. Intake of the prepartum group should be measured daily and diets formulated according to the observed intake at the farm. The recent NASEM Dairy Cattle (2021) suggests that cows require 100 kcal of net energy for lactation per kg of metabolic body weight for their maintenance. An additional 4 to 5 Mcal/day are needed to support fetal growth in the last three weeks of gestation. Thus, a typical prepartum Holstein cow requires approximately 13 to 14 Mcal for maintenance plus another 4 to 5 Mcal for pregnancy. Diets should be formulated to supply approximately 18 to 19 Mcal/day for a large frame Holstein cow.

Protein supply is also important and nulliparous (lactation 0 prepartum) and parous cows (lactation > 0 prepartum) have different needs for metabolizable protein (Husnain and Santos, 2019). Nulliparous cows have lesser intake prepartum than parous cows (NASEM Dairy Cattle, 2021; Husnain and Santos, 2019), which results in reduced supply of metabolizable amino acids for a given diet. Thus, the same diet fed to a nulliparous and to a parous cows will result in distinct metabolizable amino acid supply because of the differences in dry matter intake. Nulliparous cows have increased needs for growth and accretion of lean tissue (NASEM Dairy Cattle, 2021). Very likely, nulliparous cows also have greater needs of nutrients, including amino acids, for developing the mammary tissue compared with parous cows. Altogether, these differences justify the distinct needs for metabolizable protein between nulliparous and parous cows. Husnain and Santos (2019) showed that parous cows did not benefit from metabolizable protein beyond 800 to 900 g/day, whereas nulliparous showed a linear response in fat-corrected milk when the metabolizable protein prepartum increased up to 1,100 g/day. The impacts of protein supply prepartum and health on the subsequent lactation remain unknown at this time.

▪ Forage Quality Remains Critically Important

Limiting adipose tissue gain and maintaining rumen fill prepartum have been important components of diet formulation during the dry period. Overfeeding energy in the form of highly digestible carbohydrates results in weight gain, mostly body fat, and is linked with increased depression of dry matter intake in the last days of gestation (Drackley and Cardoso, 2014). Cows that suffer from a marked reduction in dry matter intake in the last week of gestation are more likely to eat less in early lactation and to develop ketosis and displaced abomasum, with consequences for other diseases. Supplying sufficient forage NDF is important to maintain rumen fill, to ensure rumination, and to dilute the digestible energy density of the diet. A common method has been the incorporation of straw or less digestible forages into prepartum diets (Drackley and Cardoso, 2014). Such diets have been successfully implemented, particularly in herds with high risk of having cows developing displaced abomasum. Nevertheless, cows do not require 'straw' in their diets but benefit from forage NDF.

Stone et al. (2012) tested the hypothesis that improving forage NDF digestibility during the last three weeks of gestation and first three weeks of lactation affects production performance of dairy cows. The authors fed Holstein cows prepartum diets containing approximately 72% forage and replaced conventional whole plant corn silage with whole plant silage made from brown mid-rib corn (BMR). Corn silage made up approximately 47% of the prepartum diet. Postpartum, for the first three weeks of lactation, cows were fed diets with one of the two corn silages, and they represented approximately 40% of the diet DM. After three weeks postpartum, all cows were fed the conventional whole plant corn silage. Prepartum and the first three-week postpartum diets contained, respectively, 44 and 33% total NDF, and 39 and 26% forage NDF. Thus, these transition cow diets had adequate to high content of forage NDF (NASEM Dairy, 2021). As expected, the BMR corn silage reduced the dietary lignin content and increased 30-hour *in vitro* NDF digestibility. Cows fed the BMR corn silage ate 1.1 kg/day more dry matter in the last two weeks of gestation (14.3 vs. 13.2 kg/day) and 2 kg/day more during the first three weeks of lactation (20.1 vs. 18.1 kg/day). Once all cows were fed the same corn silage from four to 15 weeks of lactation, intake no longer differed. A very important aspect of the experiment was that cows fed the BMR corn silage during the transition period not only produced more 3.5% fat-corrected milk during the first three weeks postpartum (42.9 vs. 38.8 kg/d), but the increase in fat-corrected milk persisted beyond the period of treatments. Cows fed the BMR silage produced an additional 2.7 kg/d (49.4 vs. 46.7 kg/d) from four to 15 weeks postpartum, when

they were fed the same diet as those in the conventional corn silage group. Perhaps part of this extended increase in production was caused by the stimulation in dry matter intake during the transition period and part by the tendency to reduce disease events observed in the experiment (Stone et al., 2012).

■ Supplement Nutrients and Feed Ingredients that Benefit Reproduction

Experiments designed to evaluate effects on reproduction typically require hundreds of cows per treatment. This is a difficult task when the intervention is applied to the diet and cows should be fed the treatments individually. Most experiments involving nutrition and reproduction suffer from a common limitation — insufficient power to test the effect on pregnancy per AI or maintenance of pregnancy in cows. Oftentimes, results are extrapolated from small experiments or never replicated in subsequent experiments. The science of the effects of nutrition on reproduction in dairy cows remains infantile largely because of the inability to conduct properly powered experiments. Nevertheless, one group of nutrients that has consistently been shown to improve reproduction in dairy cows is fatty acids.

Increasing dietary fatty acids from the traditional 2.5 to 3% of the diet dry matter to 4 to 4.5%, by adding supplemental fat sources, improves pregnancy per AI and reduces days open (Rodney et al., 2015). The benefits to reproduction are observed concurrent with improved production performance because cows supplemented with fatty acids produce more milk than non-supplemented cows (Rodney et al., 2015). The mechanisms for improved reproduction are multiple, with effects on follicle development and progesterone secretion by the corpus luteum, improvements in fertilization and embryo quality, changes in endometrial function, and increased maintenance of pregnancy (Santos et al., 2008). A common misunderstanding is that the benefits to reproduction from supplemental fatty acids in early lactation are caused by improvements in energy balance. Feeding supplemental fats seldom affects energy balance in early lactation and the benefits to reproduction are observed regardless of changes in body weight or energy balance (Santos et al., 2008; Rodney et al., 2015). Nonetheless, the effects on reproduction vary with the type of fatty acid fed and usually unsaturated fatty acids tend to be more beneficial to reproduction. Thus, providing moderate amounts of supplemental fatty acids to increase the total dietary content up to 4.5 to 5% of the diet dry matter should be part of the early lactation diet to promote not only production performance, but also reproduction.

■ Conclusions

Transition cow programs should be designed to accommodate the numerous needs of the pregnant cow. Providing proper cow comfort is a must. Cows should spend sufficient time in the prepartum group to benefit from what is provided to them at that time, which should include a diet that meets the nutrient needs of the cow and reduces the risk of diseases. Managing body condition in the preceding lactation remains pivotal for the success of the subsequent lactation. Lipomobilization is an adaptive mechanism to meet the energy needs when intake is insufficient, but when excessive weight and tissue loss occurs, health and reproduction are compromised. Inflammation is a common denominator of almost all diseases that affect dairy cows and, although important to contain the disease process, the inflammatory response depresses appetite, alters nutrient partition, and often causes damage to tissues that have negative consequences to production and reproduction.

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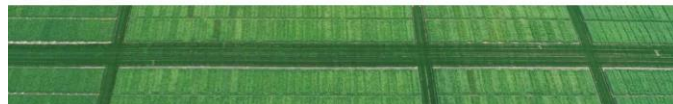
The image features a green nitrile glove pointing upwards with its index finger. To the right of the glove are two bottles of veterinary products. The first bottle is white with a green cap and is labeled 'Bioestrovet'. The second bottle is brown with a green cap and is labeled 'Fertiline'. Below the bottles is the Vetoquinol logo, which consists of a stylized 'V' inside a circle, followed by the word 'vetoquinol' in lowercase. Below the logo is the tagline 'ACHIEVE MORE TOGETHER'.

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Mining Dry Period Data for Insights into Improved Lactation Performance

Barry Bradford¹ and Katie Meier²

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■ Take Home Messages

- Short gestation length is the main contributor to poor performance in the ensuing lactation.
- There is little evidence of negative impacts from moderately short dry periods (e.g. 40 – 50 days)
- Cows with greater production potential (e.g., those with greater previous lactation milk yield) were most negatively impacted by a short gestation.
- Managing for shorter dry periods (e.g., 45 days rather than 60) is feasible.
- Cows with long lactations followed by long dry periods are at greater risk of removal after calving, likely due to poor metabolic health.

■ Introduction

The dry period of the dairy cow allows time for the mammary gland to undergo involution, proliferation, and differentiation, which in turn allows for maximal production during the following lactation (Capuco et al., 1997). In addition, during the three weeks preceding calving, specific diets are fed to reduce incidence of metabolic disease after calving. These well-established routines for dairy cattle management remain under investigation, but 'no dry period' management strategies are not widely adopted in North America. Nevertheless, nuance remains regarding exactly how long a dry period should be for optimal health and productivity outcomes, along with varying opinions regarding the 'flex' that can be built into the system. For example, many farms dry off cows once per week, meaning there is a 7-day variance in expected dry period length, even if no cows are missed. Is this too wide? Or is there room to allow a 14-day variance in dry period length and benefit from only needing to dry off every 2 weeks? These questions have important implications for optimal dairy herd management.

■ Decades of Research

Even if dry period management is relatively uniform across North American dairy farms, the consistency and precision with which those protocols are applied can be variable across farms. Dry periods that are substantially shorter or longer than 60 days have been associated with negative effects on dairy cattle productivity in the subsequent lactation. Many retrospective observational studies in the 1970s to 1990s were conducted to identify an optimal dry period length (Schaeffer and Henderson, 1972; Funk et al., 1987); however, these studies are criticized due to the nonrandom assignment of cows to dry period length. As discussed in the review by Bachman and Schalrer (2003), the short dry periods in these studies were unplanned and likely mostly composed of cows that calved early for various reasons. Milk yield of cows following these unplanned short dry periods is often less compared with that of cows that achieve the intended dry period length. In contrast, Smith and Legates (1962) reported that cows with the shortest dry period were those with greatest milk production; however, length of dry period considered short was ≥ 51 days. Milk production was speculated to be lesser for cows with long dry periods in these studies because low milk production is a typical reason for early dry off and therefore extended dry period; again, a biased population calls the result into question. Makuza and McDaniel (1996) were the first to at least account for some of the aforementioned bias by including previous days dry and previous milk yield in the statistical

model when evaluating the effect of days dry on subsequent milk yield.

A retrospective study by Pinedo et al. (2011) incorporated herd records on 12,000 cows from 223 farms and evaluated the associations between dry period length and milk production, milk somatic cell count (indicative of mastitis and mammary infection), reproductive performance, and retention in the herd. Cows were managed according to individual farm target dry period length (60 days for most herds), but were grouped and analyzed by intervals of actual dry period length. Short dry period (0 to 30 days) and extended dry period (143 to 250 days) were associated with increased odds of subclinical mastitis in early lactation, decreased reproductive performance and decreased milk yield. Although these results provided evidence that deviations from the target dry period length can be detrimental, there was no context for the reasons causing the short or long dry periods. Another caution is that the study population represents Chilean dairy herds with a herd size between 37 and 800 cows with average 305-d milk production of 7,429 kg/cow which does not adequately represent our target population in the United States where herd size is continuously increasing and 305-d milk production per cow is up to 10,430 kg (National Agricultural Statistical Service, 2017).

A major factor influencing dry period length is gestation length. A more recent retrospective observation study used records from 2 herds (United States, herd size > 1,500 cows) to investigate the effects of gestation length on productivity (Vieira-Neto et al., 2017). Cows with short (> 1 standard deviation below the mean) or long (> 1 standard deviation above the mean) gestation length had greater incidence of dystocia, stillbirth, retained placenta and metritis. Milk production was greatest for cows with an average gestation length. Interestingly, short gestation length of the dam also affected their offspring; female offspring had a greater rate of removal than heifers from cows that experienced an average gestation length.

The many factors influencing dry period length can be categorized as management or biological. When evaluating the effects of dry period length on cow productivity, observational studies such as those by Makuza and McDaniel (1996) and Pinedo et al. (2011) did not differentiate causes of a short or long dry period. Vieira-Neto et al. (2017) solely addressed the influence of gestation length (biological) on cow productivity. To our knowledge, no previous study evaluated the links between productivity and dry period length due to both biological and management factors simultaneously.

▪ Our Approach: Untangling Gestation Length from Dry Period Length

We hypothesized that cows with a dry period deviating from their intended dry period length (short or long) because of biologically shorter or longer gestation lengths have more severe impacts on cow productivity compared with cows deviating because of management reasons.

We used herd records from 16 U.S. herds in a retrospective cohort study to evaluate the effects of an unintended short or long dry period caused by deviations in gestation length or time of dry off on dairy cattle health and performance in the subsequent lactation (Olagaray et al., 2020). Herd inclusion criteria were as follows: Holstein cows; ≥ 900 cows; use of Dairy Comp 305, PCDART, or DHIA-Provo herd management software; exclusive use of AI breeding; available individual cow milk yields at least every 60 days; and consistent recording of breeding date, dry-off date, and calving date. Data were extracted from the herd records and merged with data obtained from a brief questionnaire for each farm. Herd data were incorporated into a database to allow for analysis of cow-level independent variables while accounting for herd.

In total, after cleaning the dataset, we had 32,182 lactation records to use for testing our hypothesis. These records were separated into nine study groups. For both gestation length and dry period length, populations within a herd were analyzed to determine the mean and standard deviation (SD) for the two variables. Then, cows were categorized as short (1 or more SD below the mean), long (1 or more SD above the mean) or average (within 1 SD of the mean) for both variables. This generated the nine study groups (Figure 1).

		Gestation length		
		Short	Average	Long
Dry period length	Short	$S_D S_G$ $n = 2,123$	$S_D A_G$ $n = 1,418$	$S_D L_G$ $n = 50$
	Average	$A_D S_G$ $n = 1,759$	$A_D A_G$ $n = 19,265$	$A_D L_G$ $n = 3,325$
	Long	$L_D S_G$ $n = 310$	$L_D A_G$ $n = 2,573$	$L_D L_G$ $n = 1,719$

Figure 1. Schematic showing the composition of the nine study groups used to assess independent impacts of short (S), average (A), and long (L) dry periods (D) and gestations (G).

Although in theory nine groups were available, in reality, too few cows had a long dry period and a short gestation, and too few had a short dry period and a long gestation. These two groups were dropped from analyses due to poor sample sizes.

Because distribution analysis of dry period and gestation length occurred within a farm, there was some overlap in the distribution of these variables across the overall dataset. Nonetheless, the differences among groups were clear (Figure 2).

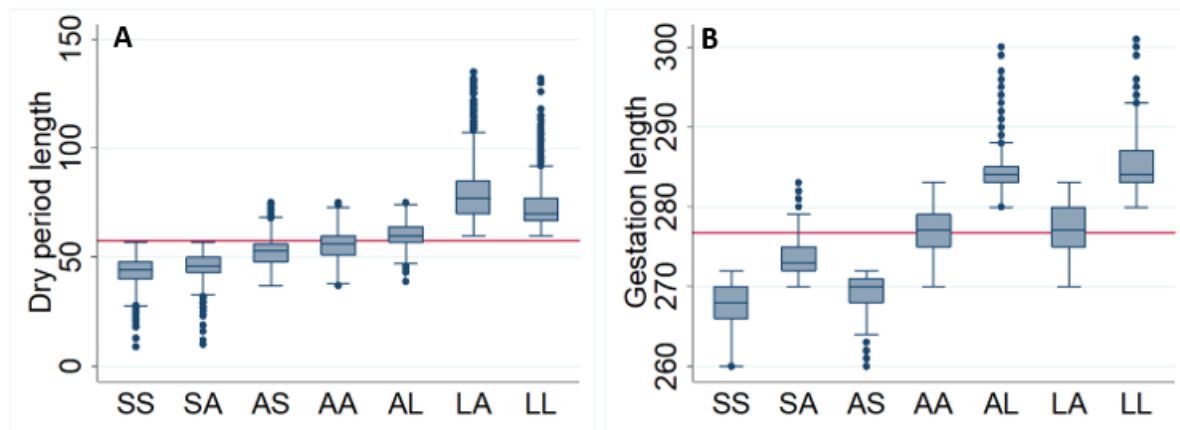


Figure 2. Distribution of (A) dry period length and (B) gestation length across study groups. Cows classified as having short (S), average (A), and long (L) dry periods averaged 45, 56, and 74 day dry periods, while cows classified with short, average, and long gestations averaged 269, 276, and 284 day gestations, respectively.

One simple insight from this study is that modern Holstein cows have an average gestation length of around 276 days, several days shorter than reference tables typically show.

In terms of productivity outcomes, significant differences among study groups were already apparent at first milk test. The most meaningful difference was in milk fat yield, which was decreased in both short-gestation study groups compared to the reference population (average dry period and gestation, Table 1).

Table 1. First-test milk variables for seven study groups varying in dry period and gestation lengths. Means that do not share a superscript are significantly different from one another. LSC: linear somatic cell score; SEM: standard error of the mean.

	S _D S _G	S _D A _G	A _D S _G	A _D A _G	A _D L _G	L _D A _G	L _D L _G	SEM	P-value
Milk yield, kg	38.72	41.58	39.78	42.37	42.91	42.63	43.11	1.00	0.16
Milk fat concentration, %	4.04	4.10	4.08	4.05	4.07	4.08	4.04	0.10	0.002
Milk fat yield, kg	1.61 ^c	1.72 ^{ab}	1.69 ^b	1.75 ^a	1.77 ^a	1.74 ^{ab}	1.75 ^{ab}	0.06	< 0.001
Milk protein concentration, %	3.17 ^a	3.14 ^{ab}	3.12 ^{bc}	3.10 ^c	3.09 ^c	3.05 ^d	3.03 ^d	0.02	< 0.001
Milk protein yield, kg	1.27	1.31	1.29	1.33	1.34	1.34	1.31	0.03	0.65
LSC	2.37	2.59	2.39	2.38	2.47	2.41	2.41	0.18	0.08
Fat:protein concentration	1.29	1.32	1.32	1.32	1.33	1.34	1.34	0.03	0.54

Whole-lactation productivity was also most negatively impacted by short gestation, although a short dry period appeared to exacerbate the negative impacts. This group produced significantly less milk, fat, and protein than the reference group (Table 2).

Table 2. Whole-lactation variables for seven study groups varying in dry period and gestation lengths. Means that do not share a superscript are significantly different from one another. LSC: linear somatic cell score; SEM: standard error of the mean.

	S _D S _G	S _D A _G	A _D S _G	A _D A _G	A _D L _G	L _D A _G	L _D L _G	SEM	P-value
305-ME milk yield, kg	12,204 ^b	12,526 ^a	12,408 ^a	12,537 ^a	12,505 ^a	12,296 ^a	12,542 ^a	255	< 0.001
Milk fat concentration, %	3.68	3.69	3.66	3.67	3.70	3.65	3.67	0.07	< 0.01
Milk fat yield, kg	436 ^b	451 ^a	446 ^{ab}	452 ^a	455 ^a	448 ^a	454 ^a	15	0.03
Milk protein concentration, %	3.16	3.13	3.11	3.11	3.10	3.08	3.07	0.03	< 0.001
Milk protein yield, kg	372 ^c	378 ^{ab}	375 ^{abc}	379 ^a	380 ^c	372 ^c	373 ^{bc}	7.9	< 0.001
LSC	2.43	2.29	2.41	2.36	2.39	2.43	2.33	0.17	0.17

The survival analyses were even more interesting. As shown in Figure 3, three groups left herds much more quickly than other groups in the first 60 days of lactation: both groups with short gestation lengths and the long dry period group with average gestation length. Color-coded study groups are graphed to show the rate of removal from herds.

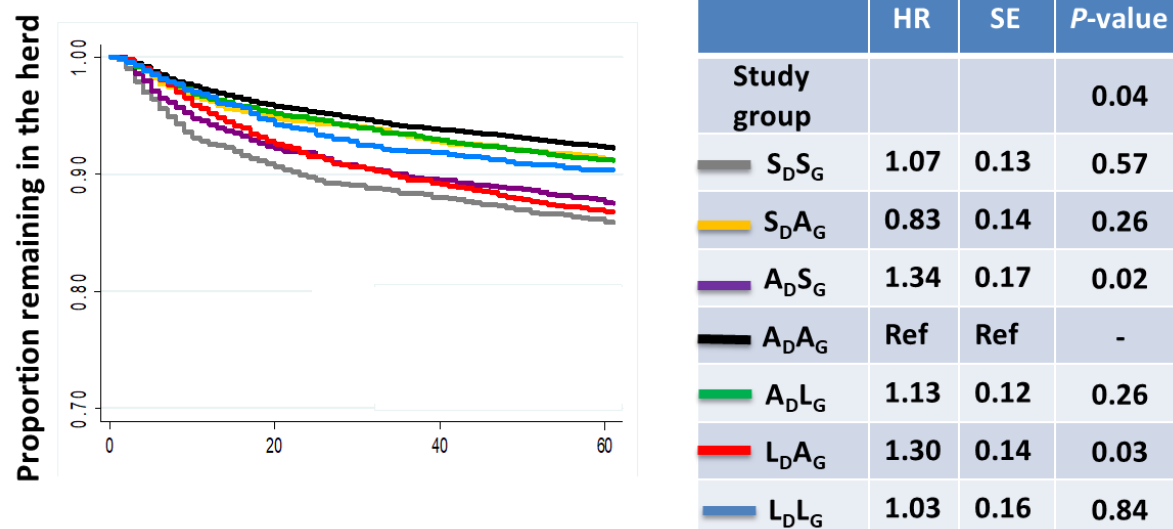


Figure 3. Retention in the herd over the first 60 days in milk. Color-coded study groups are graphed to show the rate of removal from herds, while the accompanying table shows the hazard ratio (HR) for the group compared with the reference population, after adjusting for other factors (e.g., parity). An HR of 1.34 indicates a 34% increased risk of removal over this window of time compared that of cows with an average dry period and gestation length.

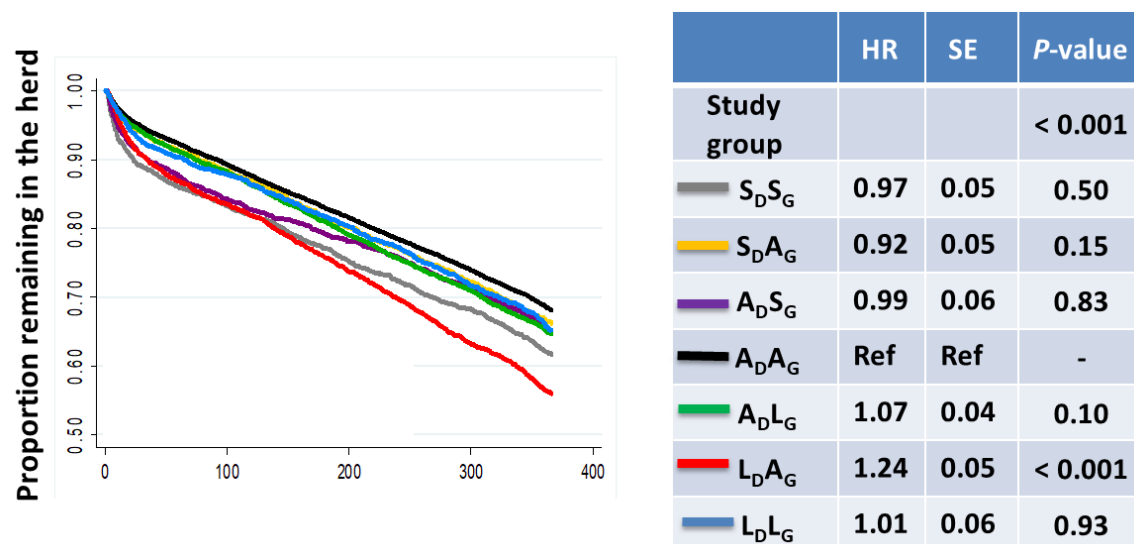


Figure 4. Retention in the herd over 365 days after calving.

Figure 4 shows the hazard ratio (HR) for the group compared with the reference population, after adjusting for other factors (e.g., parity). An HR of 0.97 indicates a 3% decreased risk of removal over this window of time compared with that of cows with an average dry period and gestation length.

Over nearly the full inter-calving interval (365 days), it was the long dry period group with average gestation length that stood out for having a 24% increased removal rate compared with the reference population. This group also showed greater fat:protein ratios in early lactation, and these relationships were more extreme for cows with a long previous days open (long lactation + long dry period). These results, in our minds, point clearly to a subset of cows that became over-conditioned prior to the calving event evaluated here, resulting in excessive body fat mobilization, poor fertility, and greater culling rate.

■ Conclusion

What did we learn from this mountain of data (Olagaray et al., 2020)? Short gestation length is the main contributor to poor performance in the ensuing lactation. We know that many physiological stressors, including heat stress, disease, and chronic inflammation, can trigger early calving. It is likely that these stressors are what actually lead to the decreased performance, rather than a short dry period causing these outcomes *per se*.

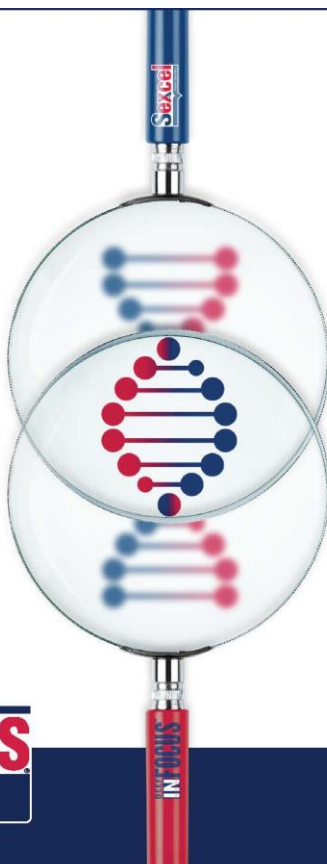
There was little evidence of negative impacts from moderately short dry periods (e.g., 40 – 50 days), except that cows who also calved early seemed to have more negative outcomes. In this study we were not able to assess days in the close-up pen, and it's possible that shrinking this period (especially) at both the beginning and the end had more negative consequences. In our publication, we demonstrate that cows with greater production potential (e.g., those with greater previous lactation milk yield) were most negatively impacted by a short gestation.

Managing for shorter dry periods (e.g., 45 days rather than 60) seems feasible based on this study, with a few caveats. Cows that dried off with high milk yield seemed to benefit the most from a 'full' dry period, suggesting that delaying dry-off because of concerns about a cow giving too much milk may be counter-productive. Additionally, cows with short dry periods with an average gestation length had, on average, greater somatic cell counts at first test. These results add to the long list of findings that remind us that cows with long lactations followed by long dry periods are at great risk of removal after calving, likely due to poor metabolic health and effects downstream of that. We found few impacts of long gestation length, with the caveat that we did not have consistent data on calving ease across herds.

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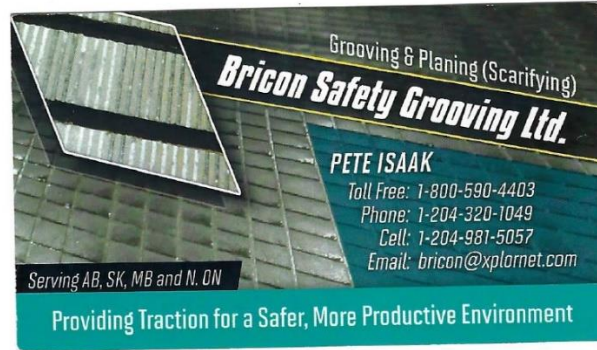
A close-up photograph of a brown and white cow's head as it licks a newborn, dark brown calf. The calf is lying in a bed of dry straw. The cow's head is positioned above the calf, and its tongue is visible, licking the calf's head. The cow has a blue collar around its neck. The background is filled with straw.

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A Producer's Perspective on Best Practices in Robotic Barn Design

Anton Borst

Halarda Farms. Email: office@halarda.ca

▪ Take Home Messages

Robots can do a great job of milking our cows and they can provide a lot of data for management. Farmers often transition to robotic milking with the goal of having significant labour savings. These goals are not always achieved. To be able to achieve labour savings many factors must be considered when retrofitting or building a new barn. When robots are only used for replacing the labour that would otherwise be assigned to milking then this is a missed opportunity.

Many factors as they relate to the planned future management strategies can affect layout and all factors should be considered before a design is decided upon.

When we are in the planning stages before construction or the retrofit process starts, we can adopt the barn design to fit the management style and preference of the farm. After construction is completed, we are forced to adapt the management style to the layout that we have. Pre-planning includes the cow traffic style that is chosen for the barn. Management preferences may help us choose our cow traffic style or our cow traffic choice will determine how we will need to manage the barn.

The correct layout for each farm depends on several factors

- New vs. retrofit
- Size and layout of existing facilities
- Future planning/ goals of the farm
- Cow management strategies
- Group sizes and strategies
- Installation challenges

The correct layout depends on the producer's management goals

- Labour
- Cows, including cow touches and training
- Cleaning and chemical use
- Stall maintenance and bedding
- Manure handling
- Feeding
- Footcare and footbaths
- Fetching/cow traffic

Using the data from the robots to create action lists and management by exception (the practice of focusing management attention only on the animals that are not performing as expected) in conjunction with adequately sized and well-designed separation pens allows producers who adopt these strategies to have success with significant labour saving compared with that in parlour herds.

Many choices must be made when it comes to robot layout and cow traffic. An on-farm trial at Halarda Farms Ltd. that included free, guided and hybrid traffic provided some insights in how cows responded under these different systems. Hybrid cow traffic is a cow traffic layout that combines many of the benefits for the cow of free cow traffic with the labour savings of a guided traffic barn without the negative effects of having all animals that need to be milked going through a commitment pen. During the trial it became apparent that all systems can work yet there were clear differences in cow behaviour when running them all at the same time.

In addition, robot box layout configuration in the pen will have an impact on cow behaviour. There are some clear improvements in cow traffic with robots set up in tollbooth configuration in conjunction with hybrid cow flow and making sure that cows that have just exited the robot box move away from that area and go to the feed bunk. With this configuration many negative animal interactions can be eliminated as well as many refusals or unnecessary robot visits by cows that do not have milking permission.



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Preparing for the Next Big Disease: Surveillance, Biosecurity and Other Key Steps in Emerging Disease Preparedness

Glen Duizer

Chief Veterinary Office, Government of Manitoba, Winnipeg, Manitoba, Canada, R3T1S4. Email: glen.duizer@gov.mb.ca.

■ Take Home Messages

With the rise of emerging and re-emerging diseases, producers can take many steps to protect their herds; these steps do not need to be extremely difficult and problematic. There are three key areas producers can consider to be prepared:

- building on the herd health and disease prevention activities already happening on the farm,
- expanding existing networks and communications to stay informed,
- sharing information and developing basic emergency plans that include steps needed for disease outbreaks.

Topics covered will include:

- Biosecurity: What producers can consider for basic and advanced steps in biosecurity and biocontainment. What are the different types of risk to consider, what are the easiest to mitigate, and what can be learned from other sectors?
- Surveillance: How producers can participate in surveillance and use surveillance information, especially through routine herd health and diagnostics. What WeCAHN–Dairy (Western Canadian Animal Health Network) is and how producers can make use of the quarterly reports.
- Information sharing: Why producers may consider ad hoc and formal information sharing essential for disease preparedness and response. What producers can do to share information effectively and efficiently without compromising privacy. What examples already exist and are working.
- Traceability: The basics producers already do and the importance these play in both preparedness and response. Examples of how traceability is used in disease outbreaks.
- Emergency preparedness: What producers may want to think about in preparing for a disease outbreak; what are the simplest and easiest to implement and what are the advantages of having basic plans.

In summary, producers may find value in strategically focusing on several critical areas to prepare themselves for emerging and re-emerging diseases. These need not be costly or demanding; a lot of efficiency and effectiveness can be gained with specific targeted changes and approaches.



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When Disaster Strikes: Living through the BC Floods

Lisa McCrea Hemphill

Veterinarian and Partner Agwest Veterinary Group Ltd, email: lmccrea@agwestvet.com

■ Take Home Messages

- Natural disasters happen. There is no way to completely prevent them, and the dairy industry must be prepared.
- The BC Floods affected more than 1,000 farms, 15,000 hectares of land and 2.5 million livestock. Damage to BC dairy farmers totaled between \$22 and \$100 million.
- Approximately 23,000 dairy cattle were in the Sumas Prairie region prior to the floods. Thanks to the quick work of dairy farmers, an estimated 6,000 cattle were evacuated to other farms in Abbotsford, Chilliwack, and Agassiz.
- The BC Floods brought out the resilience of the agricultural community. Dairy farmers trailered cattle nonstop day and night and local farmers, affected by the flood themselves, organized lunches and donations of cash, gift cards, and supplies to those affected by the floods.

■ Introduction

The year 2021 went down in history as one of the worst years for BC farms. In June, a heat dome brought record temperatures of 49.6°C, resulting in BC dairy farms seeing decreased milk production, up to 25%. The summer brought forest fires, leaving many BC interior farmers in high alert for evacuation, having to hose barns and homes. Then came November 14th.

■ Perfect Storm

On Sunday, November 14th, 2021, an atmospheric river resulted in 154 mm of rainfall in Abbotsford, BC over a 24-hour period, which produced extreme water flows in multiple river basins, including the Nooksack, Chilliwack, Coquihalla, Coldwater, Similkameen and Tulameen. On November 15th, 2021 the Nooksack River breached its banks in Emerson, WA, allowing water to flood into the west end of Sumas Prairie by early afternoon. In the early hours of November 16th, 2021, the Sumas River Dyke overflowed and broke, allowing the east end of Sumas Prairie Lake Bottom to flood. Late into the night of November 16th, 2021, volunteers worked to reinforce the Barrowtown Pump Station. Their tireless efforts allowed the Pump Station to hold until the Fraser River waters went down low enough for the Flood gates to be opened.

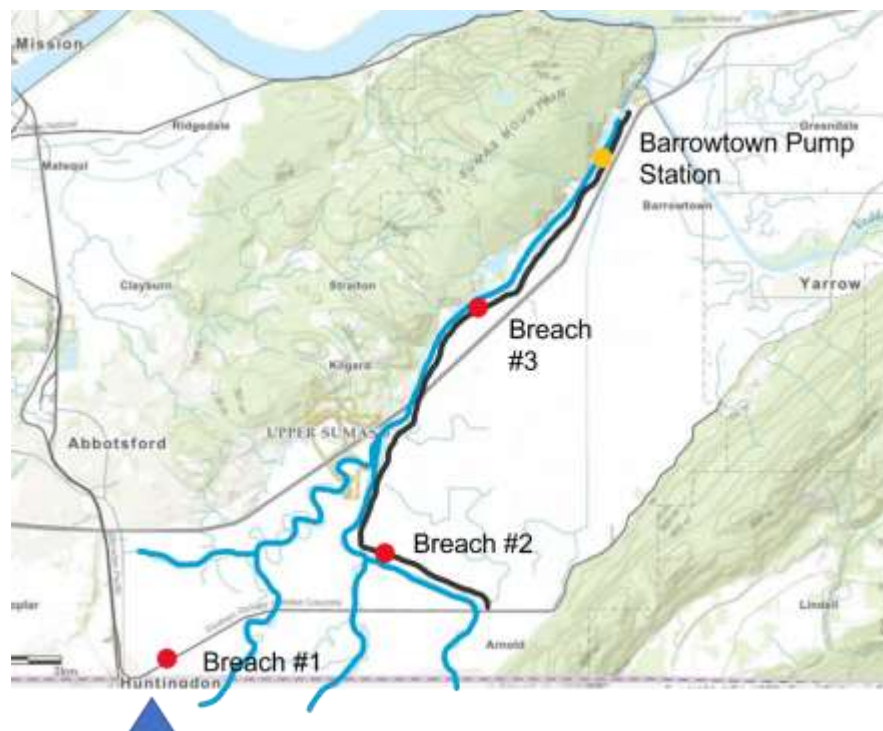


Figure 1. This map of Sumas Prairie depicts the three areas where the waters breached, flooding the west end of Sumas Prairie first, the east end of the Sumas Prairie second, and eventually flooding the entire east end of Sumas Prairie Lake bottom.

▪ One Veterinarian's Perspective

Every farmer and resident living or working in Sumas Prairie has their own unique story of what happened during the 2021 BC Floods. On Monday morning, November 15th, 2021, I arrived at work with the driveway leading to the barn being impassable due to standing water from the heavy rains overnight. During the morning, we received a request to house cattle from a Matsqui area farm that was flooding. Another 40 young stock and dry cows arrived at the WestGen barn by early afternoon, giving us a total of 55 animals in the barn. By midafternoon, the waters of the Nooksack River had reached the property and flooding looked eminent. Employees drove through water, past stranded cars, and waded in waist high water to get out. I stayed behind to shut up the barn and protect water from coming in as best as I could. By 9:30pm that evening, I was evacuated by kayak with three feet of water outside the barn rushing into barn as fast as it could.

The next morning, we regrouped to try and get back onto the barn property to see what we could do to get the animals out. We spent two hours on the phone to get clearance to go through the barricade. A few attempts to get to the barn with tractors and sprayers were made, however, the water was too deep and the current was too strong. It was decided to go in by kayak to access if the cattle were alive and exactly how much water was in the barn. Being told by the Chief officers of Abbotsford that another nine to ten feet of water could potentially be expected, the decision was made to let the cattle go and see if we could get them to swim to the highway where we had trailers waiting. As the cattle kept circling the barn, farmers were called upon to bring boats, canoes, and jet skis. Dozens of volunteers spent over 6 hours that day wading chest-deep in ice cold water, swimming as many cows as possible across the field to the highway and loading them into trailers. Sometime that afternoon the dyke overflowed and broke, causing the water in the east side of Sumas Prairie to start receding, which left an area around our building dry. Approximately 15 animals were bedded down close to the building and left for another night. Wednesday November 17th, 2021, the remaining cattle were rescued by tractor and trailer.

Both Agwest's clinic and barn were affected by the floods, with over three and a half feet of water in the barn and a foot in the main clinic. Our veterinarians were forced to divide resources to rescue animals and relocate the clinic, while still servicing the rest of our clients not affected by the flood. Road closures made emergency farm calls difficult, with the only access to Chilliwack being through Agassiz. The Agwest Veterinary Clinic remained under renovations for over a year and half, finally reopening to the public early 2023.



Figure 2. Pictures of the Agwest Veterinary barn and clinic during the 2021 BC Flood.

■ **Impact on Sumas Prairie and BC Dairy Farmers**

The Fraser Valley of BC experienced deep flood waters that lasted for a prolonged period, in some areas impacting barns, cutting power, and flooding homes. A total of 62 dairy farms were under evacuation order, with another 53 dairy farms under evacuation alert. Approximately 23,000 dairy cattle were in the region prior to the floods. Animal care was the number one priority and thanks to the quick work of dairy farmers, an estimated 6,000 cattle were evacuated to other farms in Abbotsford, Chilliwack, and Agassiz. Another 16,000 cattle remained on their own farms. The dairy farmers that remained with their cattle dealt with power and water outages for days, relying on generators to run the parlor and having to haul in water by tanker trucks for the cows. Milk trucks were unable to get to the farms for pick up, resulting in the dumping of an estimated 7.5 million liters of milk in Sumas Prairie during the flood. Grain and feed truck deliveries to the farms were made impossible by the flood waters, leaving helicopter delivery as the only option. The farms on the east end of Sumas Prairie were hardest hit, being isolated for days with standing flood waters.

The effects of the flood were felt long after the waters had receded. Homes had to be restored, lactating and replacement cattle were lost, other cattle suffered from disease due to stress, relocation and surviving the flood. Additionally, summer 2022 crop yields were down as much as 50-65%, leaving farms struggling to make quality rations for their herds.

■ **Lessons Learned from the BC Floods:**

The Agricultural Community is One of a Kind.

The agricultural community showed great resilience during the floods of 2021. Farmers from all around came with trailers, working day and night hauling cattle to safety. Farmers responded with boats, wading through ice cold water for hours doing what they could to help the stranded cattle. Animal care became the number one priority. Farmers refused to abandon their cattle despite the evacuation orders. Many stayed and milked and fed their herds for days without a break. Residents of the Fraser Valley brought food, filled sandbags and offered supplies to support the farms affected by the flood.

Two local farmer's wives, Jimi Meier and Alison Arends, whose own farms were also affected by the floods, felt the need to help their neighboring farms. They came together and started a Facebook page where

people could donate money, gift cards, and supplies. Over \$100,000 worth of money and gift cards, and \$55,000 of supplies, were donated to the victims of the BC Flood. Lunches were provided to the community daily at Crossroad Dairy for 6 months while the people worked to restore their homes, farms and lives devastated by the floods.

Sumas Prairie Floods Will Happen Again and BC Needs a Plan.

The 2021 BC Flood was not the first of its kind for the Sumas Prairie and it will not be the last. A comprehensive plan for flood control in the Fraser Valley must be developed. The plan should include both a timeline for dyke upgrades and flood mitigation measures, as well as emergency preparedness and response strategies. The plan should also include measures to protect the livestock within the flood region. Many natural disasters come too quickly to allow for the relocation of the 20,000 cattle and 500,000 birds in the Sumas Prairie. Considerations must also be made for the biosecurity implications of co-mingling livestock.





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All-Hazard Type Events: Producer Preparation and Response

Katherine Altman

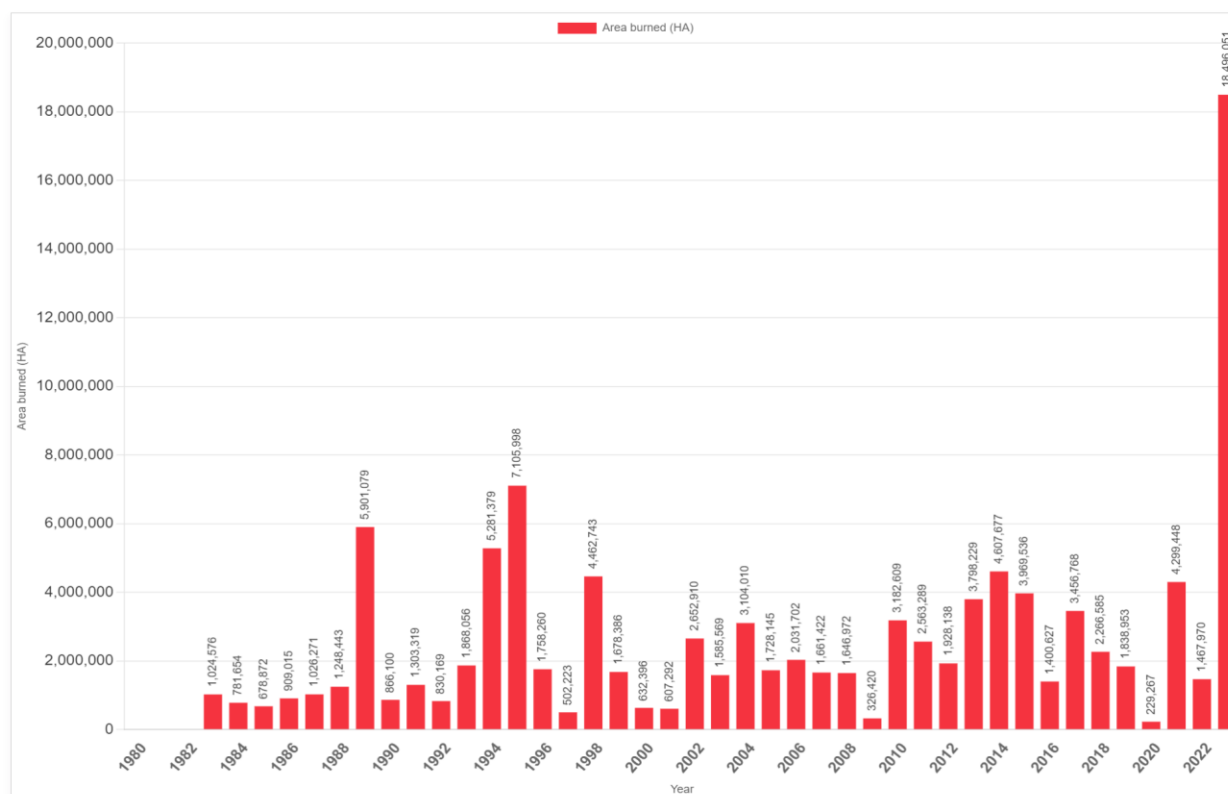
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7000 – 113 St. Edmonton, AB T6H 5T6. Email: Katherine.altman@gov.ab.ca

■ Take Home Messages

- The number and complexity of emergencies and disasters are increasing across Canada.
- The average Canadian is expected to be self-reliant for a minimum of 72 hours and people living in more remote or isolated areas should plan for a longer period of time because it will take emergency responders longer to reach those locations.
- Rural municipalities' emergency response systems, which primarily rely on volunteers, lack capacity to respond to large and complex emergencies.
- Firefighting is dangerous and has specialized training for wildland and structural firefighters. This means that wildland firefighters are generally not trained to fight structural fires.
- Rural residents, particularly ones with agricultural interests, should prepare for emergencies.
- Emergency management (EM) priorities are life safety, protect property, which includes animals and crops, followed by preserve the environment.
- Agricultural operations do not fully align with the EM priorities because they often prioritize property for protection differently; once family is safe, many producers want to protect their agricultural animals and infrastructure before their family home.
- The question about whether to shelter animals in place or to evacuate them comes with several interesting and complex factors that are unique for each agricultural operation.
- Creating an EM plan for an agricultural operation includes the following three steps:
 - Know the risks and get prepared,
 - Make an emergency plan,
 - Prepare a farm emergency kit.
- Tools and resources exist for agricultural operations to prepare an EM plan for hazards that threaten their agricultural operations.

The 2023 Canadian wildfire season should serve as a wake-up call to all Canadians.

The Canadian Interagency Forest Fire Centre, which supports wildfire response across the nation, recorded over 6,600 wildfires that burned more than 18.5 million hectares during 2023. This drastically exceeds the ten-year average of 2.7 million hectares and the 1995 record of 7.1 million hectares (Figure 1). To put the 2023 impact in perspective, the total area burned across Canada would encompass all of Alberta's farmland south of Highway 16 to the borders with Saskatchewan, the United States and British Columbia.

Annual Area Burned in Canada**Figure 1. Annual area burned in Canada (<https://ciffc.net/statistics>)**

In Canada, the responsibility to provide the initial emergency response lies with the individual or municipality where the emergency has occurred. If the local municipalities' resources are over-stretched, they can request support from their neighbouring municipalities or escalate to their provincial or territorial government, who in turn can request assistance from the Canadian federal government. This graduated system effectively uses local knowledge but can become over-stretched when large, complex, or multiple emergencies occur within a region, all of which occurred during the 2023 wildfire season.

Regardless of which level is providing the response (e.g., the individual, municipality, province or territory, federal government) the emergency management (EM) priorities are always implemented in the order of:



To meet these priorities, emergency responders generally target the areas where many people and property are located rather than isolated areas. This approach is followed even more closely when there are limited EM resources in the form of personnel, equipment, or supplies. While the average Canadian is expected to be self-reliant for up to 72 hours, remote or isolated premises should plan for a longer period of self-reliance. This is even more important for agricultural operations that often have large numbers of animals, extensive infrastructure, and a variety of hazardous materials. This recommendation is not to undermine the efforts and support that emergency responders provide agricultural operations but to highlight the fact

that their priorities do not fully align with that of the typical agricultural operation. While both groups value the safety of human lives, the emergency responders typically prioritise protecting homes over a barn and perhaps even over agricultural animals.

Following the 2023 wildfire season, Alberta Agriculture and Irrigation's Emergency Management team met with agricultural staff from 11 of the 20 directly impacted rural municipalities to facilitate an after-action review. This after-action review involved detailed discussions regarding successes, areas for improvement and significant issues experienced with how their respective municipalities responded to the emergencies. While all spoke of challenges working in a fast-paced and constant changing wide-spread environment, the common issues easily separated into three distinct categories:

- Municipal government
- Municipal agricultural service team
- Agricultural operation/ producer

At the municipal government level, the common observation was insufficient resources, either available in-house or accessible to support emergencies involving multiple agricultural operations impacted along several front lines. Coupled with this, there was a lack of knowledge regarding how the Provincial Emergency Coordination Centre (PECC) could assist in procuring resources. Examples of the types of resources that could be requested through the province include livestock transport vehicles and pasture land. Municipalities that had a livestock emergency response plan or understood how to access resources through the PECC reported less challenges and problems with responding to the emergency but still found securing resources a challenge. The absence of a plan generally meant that there was no clear understanding of what a municipality could and would do to support agricultural operations during an emergency.

This is not to throw blame on municipalities or their fire departments, which primarily comprise volunteers that undertake training, respond to emergencies, and participate in community planning outside of their regular work commitments. It is important to acknowledge that few municipalities have sufficient full-time paid staff dedicated to emergency management and response. The Canadian Association of Fire Chiefs' 2022 census showed that 71% of Canada's firefighters are volunteers. As well, rural municipalities generally rely on volunteer or paid-on-call firefighters for the majority, if not all their front-line emergency services (Canadian Association of Fire Chiefs, 2022).

Communities with plans and training were generally able to manage better. However, most rural municipalities do not have sufficient staff or enhanced training to manage either an extended or widespread emergency. Further compounding this, most agricultural service team members openly spoke of the stress associated with working long hours for multiple days where what was effective yesterday or even that morning was no longer effective by mid-afternoon. A fast-changing environment can require quick transitions from one strategy to another, often multiple times, before landing on one that fits the incident and is sufficiently resourced to be effective. Success in that type of environment without EM training and advance planning may often be limited.

Surprisingly, no reports of significant losses of either agricultural animals or structures were received, despite the provincial Premises Identification System reporting over 3,400 agricultural premises containing over 1.3 million animals across the 20 impacted municipalities. This fact seems even more surprising recognizing that local pastures and grazing leases had insufficient water and no grass when most of the fires started, many of the over 300,000 head of cattle were in spring calving, and there were limited transportation routes available to evacuate animals because of the geography. A further complication was that many municipal agricultural service team members indicated that their own homes or agricultural operations were under threat from the advancing wildfires, which put them in the unique position of being both an emergency responder and a potential evacuee.

At the individual operation level, the lack of clarity regarding who takes the lead on fighting a wildfire created confusion and frustration amongst potential evacuee's and directly impacted residents. A common

assumption is that wildland firefighters will step in to manage structural fires for premises located along or near the provincial forest areas. While Alberta's Forest Areas do have mutual aid agreements with municipalities that have 'wildland-urban interface areas' or 'wildland-urban intermix areas' (Figure 2 and Figure 3), the ability to fight structural fires requires special training as fire behaves differently pending the type of fuel (e.g., grass, trees, crops, building materials) that it is consuming.



Figure 2. Wildland-Urban Interface Area in Advanced FireSmart Home Assessment 2023.



Figure 3. Wildland-Urban Intermix Area in Advanced FireSmart Home Assessment 2023.

As such, responding to fires that span between 'wildland-urban interface areas' or 'wildland-urban intermix areas' relies on a strategic and highly coordinated approach between the provincial wildland firefighters and the various municipal fire departments. This can be further complicated when landowners take action outside of their land because there is no way of knowing where they are or what they are doing in relation to the other front line emergency responders. Several near-miss accidents involving firefighting crews and self-deployed individuals that were operating either along the very edge of their land or outside of their land were reported during the response. All response activities should be fully coordinated to support the life safety of responders.

Communication was identified as needing improvement at all levels. Municipalities referenced frustration over spending limited resources truth sourcing and correcting messages that were corrupted or muddled by unofficial statements or public social media posts that were accepted as accurate statements. Producers expressed concerns and frustrations over not receiving information early enough to make critical decisions regarding their agricultural operations, such as preparing animals to evacuate or preparing animals to shelter-in-place.

Not all species can evacuate even with sufficient notification. The ability to evacuate animals depends on each species' specific disease risks or status, production cycles (are animals calving or in high milk production phases), availability of alternate space that meets appropriate biosecurity requirements and the ability to complete transportation in the available evacuation window. Livestock evacuation, even when fully resourced, is a timely and costly process. Anecdotally, many producers who did not evacuate also indicated that they didn't 'see' anyone protecting their operation, so they felt that they had no choice but to stay and safeguard their animals and structures.

Recognizing that the decision to evacuate or shelter-in-place is often based on factors beyond the producer's control, perhaps a more relevant question for a producer is how can they effectively safeguard their operations against the most common hazards they are likely to experience? Safeguarding an agricultural operation can be effectively undertaken by producers through implementing the first two stages of the continuum, which the Alberta Emergency Management Agency defines as a cyclical 'approach to managing hazards, risks, and their potentially harmful effects'. The four stages are considered a continuum as they occur in advance of, during and following an emergency (Figure 4).

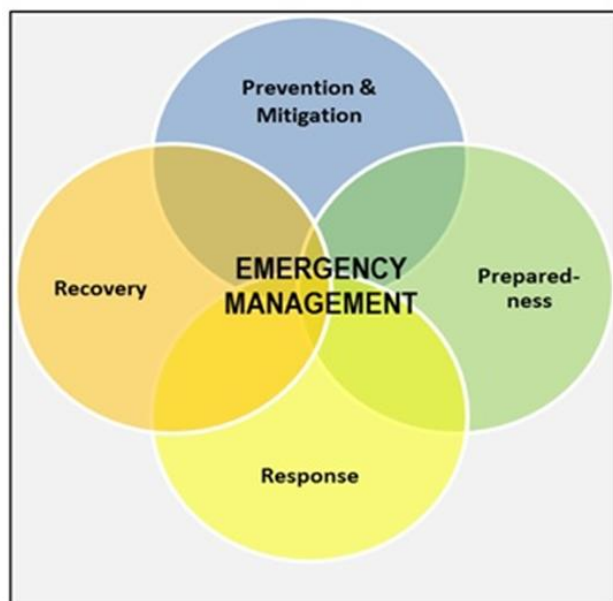


Figure 4. Emergency management continuum (<https://agriculture.canada.ca/en/sector/animal-industry/emergency-management/framework>)

The first stage of EM is prevention and mitigation, which can be done well in advance of an emergency. It involves taking actions to avoid, eliminate or reduce the impacts of an emergency. This can include structural and non-structural measures that can be as straight-forward as having an appropriate hazardous materials storage system.

The following items are considered effective prevention and mitigation actions:

- Appropriate insurance coverage
- FireSmart your property
- Address existing on-farm risks
- Participate in EM training
- Comply with by-laws, including land-use planning
- Learn what your municipality and relevant industry association will do during an emergency
- Establish an initial farm emergency plan, including key contacts
- Traceability, Biosecurity and Environment (three modules in the Dairy ProAction initiative)

While all of these can provide benefits, let's focus on a couple. The first recommendation would be to implement FireSmart on the property, which typically also addresses some existing on-farm risks. "FireSmart is the implementation of both prevention and mitigation measures to reduce wildfire threat to Albertans..." (FireSmart Alberta 2023). This initiative addresses how to protect homes through proactive measures that can be applied to other structures to help reduce and mitigate the impacts of wildfire.

As well, agricultural operations are required to participate in several initiatives (e.g., Livestock Traceability, Biosecurity, etc..) that provide invaluable information to emergency responders. The Livestock Traceability's Premises Identification (PID) System data, such as the contact information and type of operation, can be shared with a municipality to help them prepare and respond to emergencies. This data is often used to send out early notifications, set up appropriate evacuation routes and allow temporary re-access for producers with animals sheltering-in-place. During a disease response the Office of the Chief Provincial Veterinarian will also rely on this data to minimize and control disease spread. Keeping Traceability PID

data accurate can make a difference between receiving a notification or being allowed to re-enter an evacuated zone to care for animals.

While learning what the municipality and relevant industry associations will do for an agricultural operation during an emergency is considered a prevention and mitigation strategy, it also carries over into the second EM stage. Preparedness consists of the following three steps:



An all-hazards approach that addresses natural hazards (e.g., floods, fires), technological hazards (e.g., dangerous good spill, hazardous materials) and man-made hazards whenever possible will undoubtedly provide the best coverage. However, identifying even the top two or three hazards that could impact the operation and determine their potential impact, which is the risk factor, will provide an excellent result. The hazards with the highest risk factors should be developed into well thought out emergency plans for the animals to either shelter-in-place or be evacuated. Both scenarios should be planned for because either may be required when responding to the emergency.

The development of these hazard specific emergency plans is the second step in EM preparedness. Agricultural operations will have similarities in their animal evacuation or shelter-in-place responses, such as access to clean food and water as well as ensuring each animal is clearly identified with a tag or marked with temporary non-toxic paint (e.g., owner's cell number) in case they get separated. Despite these similarities, there will be unique key factors of each high-risk hazard that needs to be accounted for. Floods will require access to high ground safe from power lines that may fall and pose an additional hazard of having to deal with live power lines near water. Winter storms will require shelter with sufficient space that can provide protection; barns and shelters need to bear the weight of heavy snowfall.

All emergency plans will require supplies that should be readily available and easy to transport. This is often referred to as a farm emergency kit, which is the third and final stage in EM preparedness. Farm emergency kits can contain everything from standard medical supplies, ropes, halters, temporary fencing and even supplies for the temporary identification of animals. The farm emergency kit needs to support the plans that have been developed for each high-risk hazard.

Actively safeguarding your agricultural operation consists of the following three steps:

1. Identify the top hazards and determine the high risks to your operation,
2. Make an emergency plan for the high-risk hazards,
3. Establish a farm emergency kit containing the necessary items to implement your plans.

It is highly likely that you've already thought through many of the hazards and began building emergency response plans for the high risks that threaten your agricultural operation but may not have compiled them together. The development of a plan for high-risk hazards does not have to be completed at one time; consider creating a plan for what may come next.

The 2024 year is shaping up to have significant water shortages, which most likely means an active wildfire season. The following tools and resources may assist you in developing a wildfire emergency response plan for your agricultural operation:

- Animal Health Emergency Management
 - Producer Handbook: Alberta Dairy Cattle Sector
 - Emergency Response Procedures: Non-Disease Related Emergencies
- FireSmart Begins at Home Guide
- Government of Canada's Emergency Preparedness for Farm Animals

Agricultural producers need to take the lead on safeguarding their operations instead of solely relying on under-resourced existing emergency response systems that may not reach them in time. This means working in advance to mitigate the impact of common hazards by implementing FireSmart and addressing known risks throughout the operation. Find out what the municipality will support during an emergency response and use that to develop a realistic emergency plan for your operation. Finally, take full advantage of existing support systems that are relied on by emergency responders to safeguard your operation. This means maintaining current Traceability PID contact and species data to receive timely notifications that can trigger implementing the emergency plan for your operation.

Safeguarding your family, your agricultural operation and your future is largely in your hands.

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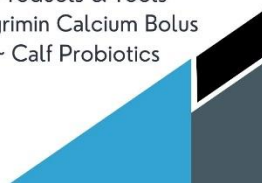
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Practicing Strategic Social Media and Media Engagement in Agriculture: Controlling the Narrative

Kevin M. Folta

Horticultural Sciences Department, University of Florida, Gainesville, FL 32611. Email: kfolta@ufl.edu

■ Take Home Messages

- Consumers are interested in understanding where their food comes from. Unfortunately, they seek this information on the internet, and while some quality information may reside there, false and misleading information is abundant, frequently discovered with better search engine placement and persuasive with aesthetically pleasing websites.
- Social media is rife with pseudo-celebrities pushing messages that malign dairy and other agricultural industries. Sadly, the sources of misinformation are compelling, and reinforce preconceived biases that misrepresent agricultural industries and products.
- The push-back solution is to actively shape consumer sentiment by controlling the narrative. Contrary to popular opinion, facts, statistics, and information rarely change minds. Controlling the narrative means presenting values-based messaging and earning consumer trust before basic information can flow.
- Producers and industry together must be present in social media space, sharing perspectives and realities of agricultural production—but doing it correctly. Consumers are asking questions—are you answering them, or is someone else with an anti-ag agenda answering for you?

■ Biting the Hand that Feeds

Efficiencies in animal and crop agriculture have ensured an abundant, affordable, and safe food supply in North America. While we always can find examples of rural and inner-city areas that are underserved and food choice is limited, these issues are almost always a function of distribution rather than production. Innovation in genetics and production technology has created crop and animal varieties that produce more with fewer inputs, lower costs, and less environmental impact. It is the very definition of sustainability.

But social media is predominantly a wall of outrage against agriculture and shapes a negative public perception. Why? Affordable access to diverse foods is a privilege and a reason to be grateful for agricultural producers and the technologies that allow today's efficiencies. Yet the frequent message in social media is that modern agriculture produces an adulterated (if not poison) product that enriches a couple of multinational companies and the greedy farmers that do their bidding.

What is the chasm between reality and the public face on social media? How much does it influence consumer behaviours?

We have innovations that allow sustainable intensification on one hand, and a public that frequently rejects the innovations that allow sustainable intensification on the other. So why isn't the public excited about the technologies that feed them?

We can blame a vigorous disinformation stream. According to a 2023 Pew Research Poll, 50% of North Americans get their news from social media at least 'sometimes', and most messages are rarely originating from legitimate news sources. Motivated misinformation or patently false information is distributed with the glitz and pizzaz of real news, providing the viewer with a sense of legitimacy to just about any claim. Most

people seek out information that confirms what they already believe, and resist content that challenges their worldview. This self-reinforcing echo chamber ensures that information-seeking web surfers only bolster their views, reaffirming beliefs that may not be consistent with the preponderance of evidence.

This situation presents a ripe ecosystem for false information to flow. Over the last several decades the internet has become the festering conduit for false information about many topics, but agriculture is a model target. Whether it is animal agriculture, crop genetics, herbicides or livestock vaccines, the internet's 'experts' are in visible, impactful space educating others about what you do.

And where are you?

This article underscores the necessity for agricultural concerns to control the narrative, with an emphasis on dairy production. The fundamental principles of public communication are shared between the dairy industry and other agricultural industries, and lessons learned and strategies employed translate well across disciplines.

The bottom line is that agricultural industries and their constituents must control the narrative. We need to tell the story of our discipline, or someone else will be happy to tell our stories for us. Unfortunately, or perhaps fortunately, this means effective engagement in social media. The challenge is engaging correctly, because connecting with a skeptical public requires a special strategy that is not always intuitive.

▪ The Perfect False Information Storm

Dairy is well positioned for derision from activist groups. Animal agriculture has its haters, vegans and others oppose milk products, and anti-biotech interests will argue against cattle feed that is predominantly produced on genetically engineered (GE) crops. Many of the internet's self-appointed experts certainly have opinions on dairy as a part of the diet. All these interests use the pipeline of the internet to push a narrative that may or may not be in line with actual evidence.

We know from the COVID-19 pandemic that most of the false information arises from a small number of sources. The Center for Countering Digital Hate has identified that 65% of false information about the pandemic arose from just 12 social media accounts. A quick Google search about the dangers of dairy reveals a suite of websites that speak to consumers with a patina of medical authority.

Malevolent interests are controlling the narrative, breeding consumer skepticism, and possibly earning consumer trust—all with false or misleading information.

▪ How Do We Take Control of the Narrative?

Harness the Power of Networks

The interests opposed to science and reason are masters of exploiting networks. From GE crops to climate to vaccines, there is a connected web of science rejectionists that build substantial followings with expanding networks.

Unfortunately, our communication within agriculture is farmer to farmer, scientist to scientist, farmer to advocate. All of us, from producers to industry employees to academics, need to build networks of individuals excited to share our work within their networks.

This means establishing an online presence. As painful as it may seem to many, this is where the conversations are taking place, and if the plan is to control the narrative, there must be participation in that space. The development of networks in social media space can provide a powerful means to transmit your own information as well as share good content others create.

Build Trust

One of the uphill battles that agriculture faces is a deficit in trust. It is not an agriculture-specific problem, but instead a systemic skepticism of professions and institutions manufactured from internet claims. Agriculture's critics come across as advocates for the consumer, with 'clean food' movements and other disinformation that implies health risk from products derived from conventional agricultural production. Purveyors of dairy alternatives will generate narratives around animal agriculture.

The new reality is that many consumers are curious about their food and how it is produced. The result is a perfect storm for false claims to grab hold, as consumers have a hard time discerning legitimate information from the copious misinformation on the internet and in social media space. What do consumers believe?

When affluent consumers in the industrialized world are faced with conflicting information, they tend to make conservative, precautionary decisions. If they are told that milk is loaded with hormones and antibiotics by a trusted (yet misinformation laden) wellness website, and an industry website explains that there are no added hormones and livestock are not used in production when being treated with antibiotics, the average person will choose to accept the precautionary information and assume the wellness website is likely correct.

So how does the industry become more trusted than Goop, The Food Babe and faux health news websites? It is a question of earning trust.

Trust is the key word in online engagement. In the book, *The Trusted Advisor*, the authors introduce the trust equation (Maister et al., 2021). The concept illustrates the elements of trust and provides a roadmap to which elements may be controlled to influence consumer behaviour. At this same time, the trust equation clearly shows how special interests manipulate the consumer by becoming the trusted sources of information. The trust equation has taken on many forms in recent years, but the basic equation is:

$$\text{trust} = \frac{\text{competency} + \text{reliability} + \text{intimacy}}{\text{self motivation}}$$

The equation shows the relationship between several attributes that influence consumer behaviour. Competency addresses the question of expertise, why should anyone be considered a trusted expert. This is where farmers and professionals in agricultural industries excel. Leading with personal stories that illustrate expertise, time in profession, involvement in professional organizations, or commitment to generational agriculture builds trust by demonstrating competence and expertise.

The second component is reliability. Whereas competence defines if you can do it, reliability asks if you are willing to do it. In this case trust may be built by providing examples of stepping up to solve a problem, being proactive in a sustainability campaign, or displaying the products of volunteer efforts.

The third element is typically a stumbling block for agricultural professionals, intimacy, or the question of 'do you care?' From the consumer's point of view agricultural industries are like any other, concerned with the financial bottom line, even if that means inflicting harm on people or planet. Such claims have become dominant in social media and on 'health oriented' websites. Warm warnings from a recognized celebrity are perceived with more intimacy than the real statistics of safety presented by academic, industry or government websites.

The numerator of the trust equation simply builds a sense of who you are—are you an expert that cares and wishes to improve a situation?

The denominator is self-motivation, why do you do what you do? Consumers perceive agricultural industries like any other, sterile, uncaring, and willing to do anything for a higher profit.

Building trust during public engagement relies on controlling several elements, defining who you are and why you do what you do.

Create the Narrative

Professionals in agriculture are too close to production to appreciate it from the consumer's lens. While the consumer is curious, farmers generally feel that their activities are of little interest to the public. After all, how can connecting an automatic milking system have any impact off the farm? However, it does. There is a newfound interest in where food comes from as well as animal stewardship. Producers need to lean into that opportunity with enthusiasm, but rarely do.

It must be stated that there are agricultural professionals that are outstanding content creators in internet space. However, as a broader industry we must do better. The paucity of individuals in social media space is unfortunate because farmers and ranchers are among the most trusted sources of information. The creation of simple content for curious audiences has never been better, as resources like X (Twitter), Instagram and TikTok provide immediate, rapid dissemination of the realities of milk production. A simple photo, a ten-second video, or an online written explanation provides material for the rest of us to share through our networks.

But are these opportunities used? Unfortunately, for the most part these are squandered opportunities to connect the curious consumer with the expert in agricultural production. While a few operations are present online (and have magnificent audiences) the critics massively outnumber the experts.

And if farmers and ranchers are not explaining the realities of agriculture, the daily successes and failures of farming, and the fundamentals of food production, then some guy in a cubicle in Oakland, CA is glad to tell that story. And this is where we are. Whole industries, dependent on the immense efforts of farmers and ranchers are out breaking ice in water troughs at 4 AM and -20°C lay silent, while the voices of opposition are stewing in ways to malign an industry via social media.

▪ **The Power of Values-Based Content**

If you don't like the media, become the media, and that sentiment has never been more real than today. Every industry understands the power of promoting its message through social media, and these conduits are more powerful and reaching than ever. Effective dissemination in this space must happen on two levels, on the industry level and on the personal level.

Professional organizations, trade groups or other producer organizations must use proactive values-based messaging in social media space. Referring back to the trust equation, how do you demonstrate competence and reliability, show that you care, and are doing what you do for the right reasons? Information presented can't be about the number of gallons produced or the supply chain, it must be personal stories of creating a nutritious, safe, and affordable product, while cognizant of minimizing environmental impacts.

On the personal level individual producers need to understand the power of a simple, five-minute effort to create content. Explaining a process, why you do it, what is important to you as a producer—these are all values-based proclamations that align with consumer values and counter the doom and gloom messaging by the websites and resources that poison public perception about agriculture.

▪ **Application: Navigating Plant-Based or Synthetic 'Milk'**

A communication strategy may be gleaned from the foibles of the plant-based meat industry, and the response from animal agriculture. As Beyond Meat and Impossible Foods ramped up their campaigns, there

was a strange and significant response by the associated meat industries. State legislatures passed laws seeking to protect animal agriculture industries, such as laws that made it illegal to refer to a plant-based patty as a burger or sausage when not generated from livestock. But how do these lobbying efforts appear to the consumer?

The natural first response is to ridicule the alternative, as a milk or meat substitute is clearly discernable from the original product it seeks to emulate. But comments against these new technologies appear petty and defensive, especially if they come from industry that stands to lose market share if alternatives rise in popularity. When these efforts reach policy change, they appear to be protectionist and defensive, which is a turn-off to consumers.

So what is the appropriate response? As in the response to fake meat, the solution to milk alternatives is not to criticize them, but instead use them as a communications opportunity to build a values-based, trust-building explanation of the benefits of the dairy product. The philosophy is simple. Criticizing the competition is easy, it's what every industry does when they sense a threat to market share. Unfortunately, today's competitive product environment is not perceived an appeal to consumer values as much as a positioning to be the lesser of two evils. But be mindful that the consumer perceives marketing-driven criticism of competitors as a sign of weakness, the machinations of an industry in the throes of decline, clamoring to retain custody of dying market share.

The way to define a positive narrative is values-based communication that extols the positives of the product, in this case dairy. What are the benefits of the animal-derived product that resonate with the consumer? Consumers seek nutrition from sources that are safe and reasonably priced. Dairy-based products, which contain a rare combination of nutrient factors that can be difficult to harness with non-dairy alternatives, can satisfy these consumer needs, as milk is a source of protein, calcium, B vitamins, phosphorus, potassium, and vitamin D. Safety is regulated at many levels from production to retail, and price fluctuations for the consumer are minor relative to the significant wholesale swings experienced by producers. Safety, nutrition, affordability, and availability are all points that align well with consumer expectations and allow messages to resonate about dairy products.

Consumers also want choices and variety. Milk products enable the production of yogurt and many cheeses that may provide bacteria that supplement digestion. Dairy products offer flavors and aromas that supplement meals, such as sour cream, ice cream and other products. Consumers in the industrialized world want choices, and dairy offers real choice above alternative 'milk' products.

This is where communications efforts need to initiate, especially in social media. The campaign should not be, "Here's what's wrong with fake milk!" and it should be, "What do we understand about consumer values and how does dairy-based milk satisfy them?" This latter question defines effective messaging, essentially defining a need and showing how the product fills it better than imposter alternatives.

Directly addressing the consumer need and ignoring the competition is a position of strength. The philosophy isn't, "Here's why the competition is bad," it is, "Here's how our products fit the needs of you and your family." Remember, imitation is the sincerest form of flattery. Milk alternatives are liquids that seek to emulate the original product, and they attempt to do this because of its sensory and nutritional qualities. Communicate that. There is a reason mimics have been spawned, and it is because the original product satisfies consumer needs.

Moreover, the original dairy product generally achieves the goals with higher quality and potentially greater sustainability. These are messages that need to propagate in social media.

What are some of the positives that may be presented in social media?

- Dairy products have been part of the human diet for over 8000 years.
- Consumption of dairy products provides a significant portion of the dietary reference intake for protein and calcium (Vissers et al., 2011).

- Dairy products provide a mixture of nutrients that are difficult to obtain from other sources (Rozenberg et al., 2016).
- Modern genetics and production technologies allow more production with fewer animals (Capper et al., 2009).
- Maximizing bone mass with adequate dietary calcium can be a key factor in staving off consequences in mineral loss later in life (Rizzoli, 2014).

■ Conclusion: Be the Solution

Dairy, like all facets of agriculture, must understand the power of influencing consumer decisions, and participate shaping them. Clearly there are efforts being made in this realm and the industry does a fine job promoting its work through websites and other advertisements. The problem is that consumers need to find them. A more proactive statement of values, building trust and shaping consumer sentiment is necessary, and that needs to happen in social media space, not just on passive websites. More importantly, individual producers need to shoulder more of the burden in controlling consumer perception, simply because they are trusted experts, and their experiences weigh heavily in shaping consumer sentiment.

Going forward, industry efforts should center on training producers in elements of trust building and content creation. Producers and other industry professionals alike must also participate in sharing good information with their networks, amplifying trust-building messages, and controlling public perception of agriculture.

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■ Take Home Messages

- Farmers considering new artificial intelligence (AI) tools should carefully select solutions tailored to their specific needs.
- Numerous AI tools have emerged to aid in the early detection of prevalent dairy cattle diseases.
- The issue of false-positive alerts poses challenges in AI-based disease detection systems.
- Language models, adept at mimicking human-like text, can be susceptible to sensitive information leakage.
- It is advisable to verify outputs of language models through reliable sources.
- Users are cautioned against asserting ownership of generated text, as it may involve copyrighted content.

■ Introduction

Throughout history, agriculture has undergone many revolutions, from the ancient practice of domesticating animals and plants thousands of years ago to the implementation of innovative farming techniques like crop rotations a few centuries back. We are now seeing another revolution, fuelled by the rapid development and increasing popularity of artificial intelligence (AI). AI tools are becoming more popular among farmers because they behave like high-tech helpers that assist with daily activities on farms. In theory, these tools use technology to monitor how animals behave and detect diseases before they even start. They also help farmers make smart choices for their operations. Imagine having a farm assistant or veterinarian that tells us when animals are getting sick or which cows to breed and when. This assistant, powered by AI and machine learning, is like a digital farm manager making sure everything runs smoothly. However, it is crucial to acknowledge that AI also has many limitations.

This article will introduce farmers to the realm of AI and related concepts in an easily understandable manner. We will delve into some of the most promising applications of AI in dairy farming while also addressing shortcomings of current AI tools.

■ What is AI About? Is it the Same as Machine Learning? What About Precision Dairy Farming?

The concepts of AI, machine learning, and precision farming are interconnected but refer to different aspects. One can think of AI as the brain of a computer system, helping machines to mimic human skills linked to intelligence such as being able to see, understand and respond to spoken or written language, analyze data, etc. Machine learning is like the neurons of this brain, that transmit and process the information, and have the distinctive ability to 'learn' or improve processes the more examples and experiences they receive. Precision dairy farming is a distinct yet interconnected concept that encompasses the use of technology for ongoing monitoring of animals, generating valuable data to guide decision-making

on farms. Machine learning and AI can seamlessly integrate into these systems, tapping on the extensive data generated in the process.

Let's delve into an example that illustrates these concepts. A cutting-edge technology gaining widespread adoption on dairy farms in Canada is the Automated Milking System (AMS), commonly known as robotic milking. Let's imagine a hypothetical AMS built on a set of technologies including robot arms, optical and milk sensors, etc., that collectively oversee and optimize the entire milking process. Keep in mind that robots are not necessarily 'intelligent' robots. Most AMS generate a lot of data, monitoring our animals in real time – a prime example of precision farming. Through the application of machine learning algorithms, our hypothetical AMS could discern patterns and correlations within the data, providing invaluable insights into the health, reproduction, and general well-being of the animals. For example, using machine learning, our system could perform intelligent tasks such as learning to clean teats of varying shapes on the fly, or alerting us to potential mastitis cases, ultimately becoming an artificially intelligent robot. In essence, in this example, our AMS embodies AI systems by executing intelligent tasks that would traditionally necessitate human intervention.

In the example above, we showcased an AMS that could be categorized as artificially intelligent. However, it's important to note that AI tools come in all formats and shapes. They encompass a diverse array of technologies, such as smartphone apps, camera systems, benchtop equipment, milk meters, ear tags, boluses, and more, typically integrated with accompanying computer software.

■ As A Farmer, How Should I Approach AI?

Farmers find themselves amidst a barrage of new AI technologies that promise to revolutionize practices, offering increased efficiency, precision, and productivity. While these advancements hold tremendous potential, a cautious approach is crucial as farmers navigate AI solutions. Farmers face the challenge of selecting the most suitable solutions for their specific needs, considering factors like their farm size, budget, and the compatibility of prospective tools with their existing infrastructure.

One critical consideration is the learning curve associated with adopting these technologies. Dairy farmers may need to invest time and resources in training to fully harness the potential of the AI solutions. Sometimes, farmers will be required to become adept at interpreting the insights generated by these technologies and translating these into action. As a general rule, farmers must consider the number of hours they are expected to put into learning how to operate this new technology, their level of comfort with it, and the estimated gains associated with the technology, and they must think of any potential disruptions to established routines and workflows. Understanding the intricacies of these technologies is essential to ensure optimal integration and prevent potential disruptions to established routines. Transitioning from traditional methods to AI-driven processes may initially pose challenges, and farmers must be prepared to navigate these changes with resilience and adaptability. In many cases, AI providers offer training and ongoing support programs to aid farmers in mastering the functionalities of their tools. Engaging with these resources can facilitate a smoother learning process and enhance the overall effectiveness of the AI solutions. In addition, farmers should approach the integration process with a discerning eye. This involves seeking advice from colleagues making use of this technology and perhaps starting with smaller-scale implementations before committing to extensive changes. Pilot projects can help farmers evaluate the impacts of AI on their operations without exposing the entire farm to potential risks.

A second important consideration is the sustainability and long-term viability of AI tools. Farmers need to assess not only the immediate benefits but also the longevity of these solutions. Concerns about continuous updates, potential obsolescence, and the overall cost-effectiveness of adopting AI systems should be carefully weighed against the expected returns. Given the dynamic nature of technology, regular updates are often necessary to address evolving challenges, enhance functionalities, and stay current with industry standards. Farmers need to be aware of whether AI providers will likely continue in business, providing regular updates to their tools at a reasonable cost. Another problem is that AI tools might become obsolete over time. Consider the following scenario: an AI tool that aids dairy farmers in choosing the correct antimicrobial for therapy during drying-off. Simultaneously, there is an industry-led initiative advocating for a reduction in

antimicrobial use on farms through the adoption of selective dry cow therapy, as well as a pushback in the use of antimicrobial classes that are important to humans. There is a conceivable risk that the tool might become obsolete, particularly if the probability of receiving updates is minimal.

Farmers should also ask AI providers about potential false alerts and how often these occur. Not only do false alarms waste time and effort, but they can also lead to unnecessary interventions causing stress to animals and disrupting established routines. Farmers may lose faith in the technology if they keep getting false alerts, which would make the technology less useful overall. Precision and accuracy in alert systems are very important for farmers to be able to act quickly on real problems, make better decisions, and improve the health of the animals. Finding the right balance between how sensitive AI technologies are to real problems while minimizing false alerts is essential for fostering a successful and beneficial integration of these tools into established routines.

Another consideration is warranted in terms of data privacy and security. AI systems often rely on extensive data inputs, and farmers must ensure that their sensitive information, such as health records and personal data, is adequately protected. Understanding the terms of data ownership and usage in collaboration with AI providers is crucial.

In essence, while the promise of AI technologies in agriculture is immense, farmers should take a cautious approach when adopting new technology, AI-based or not. Below is a list of important questions dairy farmers can make before implementing AI tools in their operations.

- **Functionality and Purpose:** What specific tasks or challenges on my farm can this AI tool address? Does this tool align with the goals and needs of my dairy operation? Once I receive an alert, what exactly will I do with this information? What is the likelihood that this is a false alert?
- **Ease of Integration:** How seamlessly can this be integrated into my farm? Is there a potential for disruptions during the implementation process? Are there potential conflicts with other technologies or tools already in use on the farm?
- **Learning Curve and Training:** What level of training is required for me and my team to effectively use this tool? Are there training resources or support provided?
- **Over-dependence:** As the system becomes fully operational, to what extent should I depend on it for critical tasks on my farm? What are the potential risks associated with system malfunctions, and in the event of such occurrences, what contingency plans are in place to ensure task completion?
- **Data Privacy and Security:** How is my farm's data handled and stored? What measures are in place to ensure the privacy and security of sensitive information?
- **Costs and Budget:** What are the upfront costs associated with adopting and implementing the tool? Are there ongoing fees or subscription costs, and how do they fit into my budget?
- **Updates and Maintenance:** How frequently does the tool receive updates, and what do these updates typically entail? Is there a clear plan for maintenance, and are there associated costs?
- **Scalability and Future-Proofing:** Can the AI tool accommodate the potential growth or substantial modifications of my dairy operation?
- **Support and Customer Service:** What level of customer support is provided by the AI tool provider? Who and how often will customer support be provided? How easy is it to contact the company?
- **User Feedback and References:** Can the AI tool provider offer references from other dairy farmers who have used the tool? Are there reviews or testimonials available from users in similar contexts?
- **Compliance and Regulations:** Does this tool adhere to relevant industry regulations and standards?

■ What are Some of the Practical Applications of AI and Machine Learning in the Dairy Industry?

In recent years, there has been a rapid growth of interest in, and applications of, AI to support dairy farms, with an almost exponential increase in the number of studies after 2010. The use of AI in dairy farming is done in tandem with precision farming tools, which consistently generate data from the livestock. The diverse array of contexts in which machine learning and AI tools are being employed for decision-making on dairy farms can be classified in different domains, including physiology and health, animal reproduction, feed intake, and others. We will focus our discussion on a select few machine learning applications that hold promise for on-farm implementation. This overview, while not a complete list of all the ways AI and machine learning can be used on dairy farms, should give farmers a good start on some of the tools that are or will be available to them in the near future.

Physiology and Health

Lameness

Lameness poses a significant health challenge in dairy farming, ranking among the top three reasons for culling cows. Identifying lame cows is crucial for maintaining herd well-being. Lame cows often exhibit an altered walking pattern, characterized by a limp or an uneven gait. They may favour one leg or show reluctance to put weight on a particular hoof. Lame cows also tend to reduce their physical activity, including walking and moving around the barn or pasture. In the pursuit of early detection, scientists have explored innovative approaches such as using machine learning analysis of locomotion data generated by accelerometers (Borghart et al., 2021). This approach demonstrated around 85% accuracy in correctly identifying both lame and normal cows, which is promising, but it is still prone to false positives. In comparison, a machine learning approach using herd health data without the need for accelerometers correctly classified nearly 75% of animals (Warner et al., 2020). Another promising avenue involves leveraging AI for the analysis of video footage to identify lame cows. One study claimed a remarkable 99% accuracy in correctly categorizing cows as 'lame' or 'not lame.' (Wu et al., 2020). However, this publication lacked explicit details on how lameness was diagnosed or defined, which is critical information for accurate interpretation of their results. Hence, while there are potential avenues for the development of automated lameness detection systems based on video footage, one can still not give reliable practical recommendations on the use of this tool based on this publication alone.

Digital dermatitis

Digital dermatitis (DD) is a common infectious hoof disease in dairy cattle characterized by painful lesions, primarily affecting the interdigital skin and soft tissues. Recently, a new technology for detecting DD in dairy herds has been developed based on the analysis of videos recorded using security cameras on farms (Cerneke et al., 2020). This approach involves two sets of cameras — one capturing videos of cows' heads to identify animals via ID tags and a second capturing videos of the cows' hooves. These videos are then fed into machine learning models that aim to detect DD lesions and determine the presence or absence of hoof blocks. The system demonstrated an accuracy of 88%, holding promise for the development of real-time DD detection systems on farms through video monitoring.

Mastitis

Considerable research and development efforts have been dedicated to creating AI applications for the early detection of mastitis on dairy farms. These applications are based on the detection of a variety of markers of inflammation, such as changes in color, swelling, temperature or abnormalities in the udder, milk components such as somatic cell count, and historical herd records. Using the udder skin surface temperature recorded using thermal infrared video footages, researchers in China reported nearly 85% accuracy of machine learning models to correctly classify animals as affected by mastitis or not. Similar values were documented by researchers at the University of Calgary using AMS data (Naqvi et al., 2022).

The general consensus seems to be that the predictive power of machine learning models to identify cows with mastitis is high, but not high enough to be implemented in practice because of too many false-positive alerts (De Vries et al., 2023). Indeed, dairy farmers generally prefer a low number of false alerts, emphasizing the importance of high specificity in disease detection systems.

In a related use of machine learning and AI for mastitis diagnostics, a UK research group used data from 1,000 farms to develop an automated mastitis classifier tool (Hyde et al., 2020). This tool analyzes cow and herd data to predict whether a mastitis case is contagious or environmental, an important distinction for effective management and prevention. Contagious mastitis requires targeted measures to isolate and treat affected cows, preventing its spread within the herd. Conversely, environmental mastitis calls for improvements in hygiene and environmental conditions to lower the risk of new infections. Impressively, the machine learning classifier achieved 98% accuracy, offering the potential for farmers to discern mastitis types promptly without waiting for milk culture results.

Another application of AI in mastitis diagnostics is in the interpretation of milk culture results from on-farm mastitis culture systems. A machine learning-powered smartphone application demonstrated comparable proficiency to human experts in interpreting milk culture results for the majority of mastitis-causing organisms (Nery Garcia, unpublished). Interestingly, the accuracy of trained farm staff in reading on-farm milk culture results matched that of the AI algorithm, meaning that the AI application can read culture plates as well as trained personnel on farms.

Heat stress

Heat stress refers to the physiological strain experienced by dairy cows when exposed to excessively high temperatures, especially when coupled with high humidity levels. Cows need a certain temperature range to be able to live comfortably. When temperatures rise above this range, heat stress occurs. The negative impacts of heat stress on dairy cows are substantial, affecting their overall well-being, milk production, reproductive performance, and immune function. Symptoms include increased respiration rates, elevated body temperatures, reduced feed intake, and altered behaviour. Researchers have developed machine learning models to detect animals suffering from heat stress using various data sources including data generated from accelerometers and reticuloruminal boluses (Becker et al., 2021). The accuracy of models ranged from 85 to 89% depending on the cooling system the cows were in (e.g., shades, sprinklers). Overall, the machine learning models demonstrated sufficient accuracy in predicting whether cows were experiencing heat stress or not for most cooling systems. This showcases promising developments in leveraging precision dairy farming tools for early diagnostics of heat stress.

Metabolic diseases

Poor metabolic status elevates the risk of disorders like ketosis and fatty liver in dairy cows. Assessing metabolic status of dairy cows commonly involves blood sampling and analysis, which may disrupt routine practices on farms. Alternatively, milk composition data that is generated monthly in milk recorded herds could potentially be used for identifying cows at risk of metabolic disorders. With this objective, researchers applied machine learning techniques to milk composition data and health records to classify early lactation cows in terms of their metabolic status. A subset of algorithms achieved accurate classification for over 80% of animals, on average, from the first to the seventh week of lactation (Xu et al., 2019).

The performance of machine learning algorithms to identify animals with subacute ruminal acidosis was recently evaluated (Wagner et al., 2020). The approach involved using data from a positioning system, which inferred cow activity based on its position relative to specific locations in the barn (feeder, resting area, and alleys) and train machine learning models to detect behaviours associated with ruminal acidosis. The machine learning models successfully identified 83% of animals experiencing subacute ruminal acidosis. However, there was a notable 66% false positive alert rate, indicating that most alerts triggered by the system were false. This parallels the challenges observed with AMS alerts for mastitis detection, which prevents the adoption of the system in practice.

Animal Reproduction

Machine learning has many applications in the context of animal reproduction. AI-powered systems can analyze data from sensors, wearable devices, or even visual cues to accurately detect signs of heat in cows, indicating the optimal time for insemination. This has been demonstrated recently, where AI-powered systems performed as well as veterinarians to detect cows in estrus based on data from accelerometers and positioning systems (Wang et al., 2022).

While these tools were effective to detect estrus, machine learning predictions of cow conception using health records containing information about parity, breed, measures of genetic merit for fertility, milk production, weight, and longevity for each cow were generally poor (Hempstalk et al., 2015). This tells us that machine learning falls short to predict which cows will become pregnant following insemination, which is not unexpected given the many factors influencing the success of pregnancy establishment post-insemination, many of which are not typically known beforehand.

Machine learning and AI solutions show promise in the domain of calving and dystocia. Machine learning models, trained on calving records, have demonstrated some level of ability to identify cows more prone to calving difficulties. The records encompassed factors such as season, calf sex, breed, previous calving history, parity, and more. While the models proved accurate in flagging potential cases of dystocia, it is noteworthy that the occurrence of false alarms was acknowledged by authors, raising important concerns for practical implementation (Zaborski et al., 2019). For calving, changes in the cow's behaviour have been used for detecting the animal approaching imminent calving. Leveraging data from neck tags and accelerometers, researchers developed machine learning models for identifying cows within 8 hours of calving. The system's positive predictive value, related to its specificity in detecting cows approaching calving, ranged from approximately 60% to 80%. In practical terms, this means that, at best, 20% of the alerts generated by this system would be false alarms.

Feed Intake

Identifying animals that are more efficient can have significant benefits for the dairy industry. Efficient animals are able to convert feed into milk more effectively, maximizing milk production and reducing feed costs for farmers. On the other hand, identifying sick animals through their feed intake can lead to early detection and treatment of diseases, preventing the spread of illness and minimizing economic losses. Therefore, developing systems that accurately measure individual feed intake can be of great value to dairy farmers. On most dairy farms, cows are fed in groups, so it is not easy to get information on how much each cow eats. A research team from Israel developed an automated system for measuring individual cow-level feed intake using cameras connected to a computer. The system relies on monitoring the disappearance of feed in front of the cow, and through machine learning, estimating the amount of feed consumed at each feeding. Although the system is in its early stages of development, it shows promising potential, especially if the data generated can be integrated into models for disease detection. The investigators reported an error rate of less than 200 g per meal, meaning that their system could be used to accurately predict the amount of feed consumed at each meal (Saar et al., 2022).

■ What About the Language Models? Are They Safe? How Should I Approach These?

Language models are AI systems that are programmed to interpret and write text that reads like it was written by a person based on the input that is given in a chat box. These models are trained on huge amounts of text data, which helps them to assimilate language patterns, relationships, and context. They use this information to come up with answers to human queries. Language models can do many natural language processing tasks, such as translating, summarizing, writing code, completing text, and asking questions. ChatGPT is an example of a powerful language model that has been used in a wide range of domains, including agriculture.

Language models can be used as a virtual assistant by farmers seeking real-time knowledge and support.

One can think of it as a super-charged Google search. As an example, a farmer could ask ChatGPT to find out about the best times to feed their cows, get help detecting mastitis in cows, or even to obtain suggestions on how to better manage the milking process. Here is a text output that ChatGPT printed out when asked the following question: “*write three sentences about how to best manage clinical mastitis cases on dairy farms caused by contagious bacteria*”.

The optimal management of clinical mastitis cases caused by contagious bacteria in dairy cows requires prompt identification of affected individuals through regular udder health monitoring and somatic cell count analysis. Swift isolation of infected cows is essential to prevent the spread of contagious bacteria within the herd. Treatment with appropriate antibiotics, under veterinary guidance, coupled with stringent hygiene practices during milking, contributes to effective control and prevention strategies.

Language models also find applications in academic contexts, exemplified by Scite, a program akin to ChatGPT that attempts to back up its responses with peer-reviewed literature. Because language models are so flexible, they seem like the ideal source of information that has all the answers to all the questions that we could come up with. Farmers could ask specific questions they are interested in and use the output to inform decision-making on farms. However, we must emphasize that these models lack consciousness, personal experiences, or opinions, which clearly demonstrates that these AI systems cannot take responsibility for the generated text or subsequent actions we take based on it. Ultimately, we as humans bear accountability for the content produced by chatbots and actions we take afterwards.

The safety of using language models lies in how they are applied. As a general rule, the following few steps are recommended when using language models:

- Cross-reference your findings: When seeking information, cross-reference the findings from your queries with trusted sources such as your herd veterinarian, trusted websites, etc. to ensure the accuracy of the information provided.
- Acknowledge limitations: Language models are pretrained on billions of sentences written in the past. They will likely not have access to the most up-to-date information or capture real-time developments.
- Do not share sensitive information: Language model chatbots are not good at keeping secrets, or forgetting them. Information entered into these models may be absorbed and potentially made available to others or used for training future models. As a general rule, avoid sharing sensitive information when interacting with language models to ensure privacy.
- Do not believe what you read: Language models, while excellent at content generation, are susceptible to errors, and the information they provide may not always be backed up by reliable evidence, including platforms like Scite. This happens because of the training process of AI language models. The training data inevitably contains misinformation, and the response generated by these models reflects these inaccuracies.

With these limitations in mind, farmers can utilize language models for various purposes, including the following: 1) Obtain quick information or summaries on agricultural practices, promising new technologies, or market trends.; 2) Edit drafts for emails, reports, articles, or social media posts; 3) Ask questions to enhance your understanding of specific topics or seek explanations for complex concepts in an easy and understandable way; and 4) Brainstorm ideas.

Remember that while language models can be useful, your own experience and knowledge are still the most important things you need to make smart decisions on your farm.

■ What About AI Ethics?

Language models are a subset of AI tools falling under the category of ‘Generative AI.’ These models, including ChatGPT, can create diverse content such as text, audio, video, and code. While the rapid development of generative AI applications is impressive, it brings forth ethical concerns, particularly in the

realm of the so-called deepfakes, which are realistic manipulations of visual and auditory content. One can think of deepfakes as a modern version of Photoshop that not only can edit photos, videos, and voices, but also create content using only a handful of previous data. The technology allows any individual, regardless of their level of ability with computers, to create videos, photos or voice that look real.

Specifically on language models, dairy farmers should be mindful of two ethical concerns. The first revolves around sensitive information disclosure. Users might inadvertently expose confidential data, such as legal contracts or personal information, to the model, potentially becoming part of the training dataset and available for future users. This poses a significant risk to data security and privacy.

The second ethical consideration relates to intellectual property (IP). As language models do not have the capacity to own copyright, users may feel tempted to claim ownership of the text output. Yet, claiming ownership of text generated by these models raises complex questions. Language models are trained on existing content, some of which may be copyrighted, potentially leading to unintentional infringement when users claim ownership of AI-generated text. As a general rule, users should refrain from claiming ownership of the generated text. In case of doubt, seeking advice from IP experts is the recommended course of action. The legal landscape regarding ownership of AI-generated content is not definitively settled, and ongoing developments may shape the future of these ethical considerations.

▪ Summary

Artificial intelligence, or AI, encompasses machines that are programmed to act like humans and perform tasks typically associated with human minds. It is likely that these tools will make things easier for managing dairy herds, especially finding diseases early on. Farmers are increasingly exposed to a variety of new tools and should identify the best solutions for their needs. As commonly done before implementing any new technology, farmers should be cautious and think about things like the size of their farm, their budget, infrastructure, learning curve, and the privacy and security of their data before adopting new tools.

In the past few years, AI tools have been developed to detect common diseases of dairy cows, such as lameness, digital dermatitis, mastitis, ketosis, and acidosis. These tools are used with precision farming tools, which constantly gather information from the animals. Farmers should also pay close attention to the number of false-positive alerts that may disrupt routines and cause actions that were not needed.

Language models are AI systems that are designed to read and write text that looks like it was written by a person. Farmers can use them as virtual assistants to get real-time information. These models cannot be held accountable for the text they create or the things we do after reading it. How they are used determines how safe they are. As a general rule, users should avoid sharing sensitive information with these systems, and double check the output using trusted sources. Users should also not claim ownership of the text that is created, as some of it may be protected by copyright.

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Machine learning-based mobile application simplifies the interpretation of on-farm culture results of clinical mastitis milk samples

B. L. N. Garcia^{1,3}, C. M. M. R. Martins², L. F. Porto², D. B. Nobrega³ and M. V. Santos³

¹University of São Paulo, Pirassununga, SP, Brazil, ²Rúmina S.A., Belo Horizonte, MG, Brazil, ³University of Calgary, Calgary, AB, Canada. Email: brenoluis.garcia@ucalgary.ca

On-farm culture (OFC) enables rapid identification of mastitis-causing pathogens, which is a key feature of protocols for selective therapy of clinical mastitis (CM). Nevertheless, the accurate interpretation of OFC results demands personnel with specialized training and experience, presenting a potential challenge for dairy farms. We hypothesized that a machine learning-based automated plate reading mobile application (specifically, Rumi; OnFarm, Brazil) could achieve OFC results interpretation with a level of accuracy comparable to that of a specialist. To test that, we designed 2 trials. First, we compared OFC reading results from a trained specialist and Rumi using mass spectrometry results as reference. We utilized 476 CM milk samples from 11 farms, which were inoculated in chromogenic media plates (Smartcolor 2), and digital images were captured and read by Rumi and the specialist 24h after incubation in the laboratory. Thereafter, we designed a second trial to compare Rumi with farm personnel users after training. We used 208 images of OFC results carried out in 150 herds enrolled in an OFC program. The images were read by Rumi and farm users, and Bayesian Latent Class Models were used to compare results of the two approaches. In Trial 1, Rumi performed as well as the specialist for most CM pathogens. In Trial 2, Rumi presented similar Se and Sp as the FPU for all major groups of pathogens causing CM, which supports its use either in the training of farm users or as a diagnostic tool on farms.

Take home message: Rumi excels in reading culture plates on farms, performing on par with a trained specialist. This positions it as a crucial tool for herds seeking to implement protocols for selective therapy of CM.

The utility of serum biochemical analytes to enhance the resilience of dairy cattle through genetic selection

R. Liu^a, D. Hailemariam^a, A. Ruiz^a, C. Baes^b, M. Colazo^a and G. Plastow^a

^aDepartment of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB, Canada; ^bCentre for Genetic Improvement of Livestock, University of Guelph, Guelph, ON, Canada. Email: rlu10@ualberta.ca

Early lactation in dairy cows is characterized by negative energy balance and compromised immune function that could lead to metabolic and inflammatory diseases. Circulating biochemical serum analytes are used as indicators of metabolic and inflammatory diseases. This study aimed to estimate the genetic parameters of serum acute phase proteins (haptoglobin, C-reactive protein (CRP), serum amyloid A (SAA)), liver enzymes (gamma-glutamyl transferase (GGT), aspartate-amino-transferase (AST), glutamate dehydrogenase (GLDH)) and 6 other serum analytes including cholesterol. Blood samples were collected from 885 lactating dairy cows on 11 commercial farms in Alberta, between 2 and 14 days in milk. Serum concentrations of acute phase proteins were determined using enzyme-linked immunosorbent assay and the other analytes were assayed using an automated biochemistry analyzer. Genotype data were collected using Illumina 100K Bovine BeadChip with 78,146 SNPs after quality control. Heritability estimates and standard errors for haptoglobin, CRP and SAA, were 0.11 ± 0.08 , 0.35 ± 0.09 , and 0.17 ± 0.07 , respectively, and the heritability of other serum analytes ranged from 0.05 to 0.39. GGT was the most heritable and AST the least. The genetic correlations between haptoglobin, CRP, SAA and other analytes varied from -0.95 to 0.91, -0.35 to 0.76 and -0.77 to 0.68, respectively. Genome-wide association studies identified QTL regions on chromosomes BTA24 and 29 for SAA, on BTA12 and 17 for GGT and on BTA11 for cholesterol. Candidate genes were then identified within 100 kb distance of significant SNPs in these regions.

Take home message: These results showed low-to-moderate heritability of serum analytes and identified genomic variants associated with serum SAA, GGT and cholesterol. This indicates the potential utility of these analytes to enhance resilience of dairy cows through genetic selection.

Effects of omega-3 fatty acids supplementation on reproduction of dairy cows

G. Madureira¹, C. Van Dorp¹, I. Witelus¹, B. Van Winters¹, M. Santos¹, I. Avalos-Rosario¹, J. Bishop², T. Hansen², S. LeBlanc¹, D. Ma¹, E. Ribeiro¹
¹University of Guelph, Canada; ²Colorado State University, USA. Email: madureig@uoguelph.ca

Our objective was to evaluate the effects of omega-3 (**n3**) fatty acids (**FA**) supplementation on ovarian and uterine functions. Cows (n=104) were assigned into 1 of 4 dietary treatments from 2 to 90 DIM: 1) Unsupplemented Control; 2) CaPO: Calcium salts of palm oil; 3) CaFO35: Calcium salts of fish oil through 35 DIM; 4) CaFO90: Calcium salts of fish oil through 90 DIM. Fat was supplemented at 1% of DM. Blood and milk samples were collected at 14, 35, and 71 DIM for analysis of FA. Estrous synchronization was performed for timed AI at 70 DIM. Ultrasonography examination of ovaries and quantification of plasma progesterone were performed on d 0, 7, and 15 after AI. On d 15 after AI, uterine flushing (**UF**) and biopsy (**UB**) were performed for analysis of FA (UF and UB) and concentration of interferon-tau (**IFN- τ** ; UF only). The dominant follicle was aspirated 3 d after PGF_{2 α} injection for analysis of FA in the follicular fluid (**FF**). Supplementing CaFO increased concentrations of EPA+DHA in plasma (38.5 vs 14.4 μ g/mL) and milk (122.9 vs 46.9 μ g/mL) at 14 and 35 DIM, which remained higher in the CaFO90 group at 71 DIM. CaFO reduced the n6:n3 ratio in plasma (4.0 vs 5.2) at 14 and 35 DIM, which remained lower in the CaFO90 group at 71 DIM. There were no differences in size of the dominant follicle and luteal volume. However, CaPO and CaFO35 had higher plasma progesterone than CaFO90. Cows in the CaFO90 group had greater concentrations of EPA+DHA in FF (29.8 vs 10.9 μ g/mL) and UB (98.8 vs 56.7 μ g/g), and had greater concentrations of EPA in the UF (0.2 vs 0.08 μ g/mL). Based on IFN- τ concentrations in the UF, CaFO35 group had higher pregnancy per AI (68.8%) than the other groups (~33.0%). In pregnant cows, CaFO35 had higher IFN- τ concentrations than CaFO90 and Control.

Take home message: Supplementation of n3 FA in the early postpartum period benefited subsequent ovarian and uterine functions but these benefits were lost when supplementation was extended until the breeding period.

Effects of protected and unprotected butyrate supplementation on growth performance and fermentation profile in dairy calves

D.R. Martinez Mayorga*, K.R. Johnston, A.H. Laarman.
 University of Alberta, *Email: drmartin@ualberta.ca

Butyrate is known to promote growth performance in calves. Uncertainty persists on whether butyrate is more effective when unprotected, targeting the rumen, or protected, targeting the small intestine. The objective of this study was to evaluate rumen protected and unprotected butyrate supplementation on calf performance, as well as rumen and small intestine pH and short-chain fatty acid concentrations. Calves (n=21) were fed MR at 900 g/d and fed calf starter and water *ad libitum*. Animals were blocked by body weight, breed, and sex, and then assigned to one of three starter treatments: 1) No butyrate, 1% w/w palm fat as a placebo carrier (**CON**); 2) 1% w/w protected butyrate (2.5% of product; **PRO**); or 3) 1% w/w unprotected butyrate (1.5% of product) + 1% w/w palm fat (**UNP**). Calves were weaned with a two-stage stepdown from d 49 to 63 of age and were slaughtered at 70 d of age. Feed intake was measured daily. Blood and weight were sampled weekly. Feces and rumen fluid were sampled at 28, 42, 56 and 70 d of age. Digesta were collected at slaughter. At day 42, UNP calves had lower rumen pH than CON and PRO. Ruminal propionate and butyrate concentrations were higher in UNP than PRO, and higher in PRO than in CON. At d 56, ruminal propionate concentrations were higher in PRO and UNP than CON. At day 70, ruminal pH in PRO was higher than both CON and UNP, while duodenal pH tended to be higher in CON compared to PRO. UNP had a higher propionate concentration than CON. PRO tended to have a higher concentration of propionate than CON. At day 70, body weight was higher for CON and PRO compared to UNP. Both CON and PRO had greater starter intake than UNP. In duodenal digesta, propionate concentrations tended to be lower in UNP than CON.

Take home message: Fermentation profile is similarly altered by both supplements, but unprotected butyrate appears to compromise growth performance during weaning. Using a protected butyrate product may increase calf starter intake and growth which may decrease the time calves consume calf starter.

Effects of outdoor access on the pathogen-specific incidence rate of clinical mastitis of lactating cows in Alberta

Berina Traub, J.J. de Boer, Anne-Marike Smid, Karin Orsel, Herman Barkema
Faculty of Veterinary Medicine, University of Calgary, Utrecht University Berina.traub@ucalgary.ca

Outdoor access for dairy cattle has many advantages, but the impact on udder health is not known. Different pathogens can cause clinical mastitis in a dairy herd and can be categorized as environmental, contagious, and opportunistic bacteria mainly based on the route of transmission. The objective of this study was to quantify the effects of housing system (i.e., indoor intensive housing, outdoor access without pasture, and outdoor access with pasture), other herd-level factors, and season on the pathogen-specific incidence rate of clinical mastitis (IRCM) of lactating dairy cows in Alberta. To achieve this, 65 farms in Alberta collected milk samples of CM cases from August 2022 to June 2023, as part of a larger epidemiological study. Additionally, information on herd-level factors, housing type, and milking system was acquired. A total of 540 CM samples were collected and cultured to identify the pathogens present in each sample. Of these samples, 410 were regarded as new CM cases, the most isolated pathogens identified were environmental: *Escherichia coli* (23%), and secondly contagious: *Staphylococcus aureus* (16%), and non-*aureus* staphylococci (14%). Of all the cultured positive isolates, 19% contained contagious bacteria (*S. aureus*), 43% contained environmental bacteria (*E. coli*, *Streptococcus uberis*, or *Klebsiella* spp.) and 14% had opportunistic bacteria (non-*aureus* staphylococci). Housing type and herd size were not associated with IRCM; organic farms had a lower median IRCM compared with conventional farms, and season (winter, spring, summer, fall) resulted in a significant effect on median herd-level IRCM. In the Spring (March 19 to June 20) IRCM was lower for contagious and environmental pathogens. Although the median IRCM for farms providing pasture and alternative outdoor access to lactating cows was lower than the median IRCM for farms continuously housing cows indoors, this association was not significant.

Take home message: No significant difference between housing systems in Alberta and incidence of clinical mastitis could be identified in this study. Organic management systems and spring season significantly decreased IRCM, whereas autumn season significantly increased IRCM.



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Testing a computer-based method to analyze and identify different *Mycoplasma bovis* strains using targeted DNA enrichment

MM Biesheuvel¹, P Morley², L Pinnel², E Doster², R Valeris-Chacin², HW Barkema¹

¹Faculty of Veterinary Medicine, University of Calgary, CA; ²VERO, WTAMU, TX, USA. Email: Marit.biesheuvel@ucalgary.ca

Mycoplasma bovis infections in dairy herds can lead to clinical symptoms such as mastitis, arthritis, and pneumonia. Additionally, certain cows become subclinical intermittent shedders. Moreover, recent research revealed considerable variation in transmissibility among 20 clinically infected dairy herds. This variability is not well understood, but it is hypothesized that strain differences could explain most of this variation, rather than external farm management factors. However, identifying strains after culture is subjective to numerous biases, and becomes especially challenging without culture. Until now, an efficient and accurate method to identify *M. bovis* strains in clinical samples is lacking. Therefore, the goal of this research was to determine how well a computer-based method, focused on enriching specific genetic material, identifies the quantity and number of milk-isolated *M. bovis* strains. At a 90% enrichment, the approach consistently allowed for the accurate inference of both the correct number and identity of strains in all tested scenarios mimicking mixed infections. Accuracy in distinguishing both the number and identity of strains diminished when the enrichment percentage was set at a lower value, such as 30%, particularly when there were six or more strains present. Strain differentiation of *M. bovis* is extremely important when it comes to controlling and eradicating infections in dairy herds, as it facilitates the tailoring of farm-specific control measures for efficiently reducing the spread and number of affected animals in a herd.

Take home message: This targeted enriched metagenomic approach, which enriches *M. bovis* DNA pieces, has proven to be successful at identification of strains based on variances in DNA nucleotides. Next steps involve applying this approach to field samples taken from animals with various disease presentations and outbreak farms to determine the strains associated with distinct clinical outcomes and transmission characteristics.

Longitudinal analysis of digital dermatitis in cattle: Identifying the bacteria initiating lesion development

Angelica Dias^{1*}, Corienne Gammariello¹, Karin Orsel¹, Jeroen De Buck¹

¹Faculty of Veterinary Medicine, University of Calgary, AB, Canada. *Email: angelica.dias@ucalgary.ca

Digital dermatitis (DD), a leading cause of lameness in Canadian dairy cows, presents challenges due to its unclear causation and pathogenesis. Considered a polymicrobial disease, it involves *Treponema* spp. and other anaerobes whose specific roles are not well understood. While previous studies have identified the core bacterial species involved in DD, the specific species initiating the lesion are still unknown. Therefore, this longitudinal study aimed to identify the bacterial species most crucial for initiating lesions and identify the opportunistic species by monitoring changes in their abundance over time. Over 12 weeks, weekly swabs were taken from both hind feet of 53 Holstein dairy cows without DD (M0 stage) in a DD-affected herd. Bacterial DNA was extracted and subjected to qPCR targeting *Treponema phagedenis*, *Treponema medium*, *Treponema pedis*, *Porphyromonas levii*, *Bacteroides pyogenes*, *Fusobacterium necrophorum*, and *Fusobacterium mortiferum*. Out of 53 cows, 8 developed DD, while 31 remained healthy, and 14 developed heel erosion. Analyses of the results have started, and we will be completed by the 2024 conference. Samples will be compared at key time points (Day 0 [DD case emerged], -1, -2, -3 and +1 weeks) between cows developing DD and those remaining healthy. We expect certain targeted bacterial species to increase in numbers before and during lesion onset, indicating their primary role in initiating DD. Conversely, secondary opportunistic pathogens are expected to increase in numbers only after the lesion has been established.

Take home message: This study is expected to yield impactful findings in DD microbiology, including the roles of DD-associated bacteria in lesion initiation, with the goal of disease prevention and targeted early interventions. The findings on lesion initiation will be useful to induce DD in experimental models for evaluating new treatments and vaccines.

Investigating what makes *Staphylococcus chromogenes* the most prevalent staphylococcus species in milk

Mohamed Ghanduri, De Buck Lab, University of Calgary; Mohamed.ghanduri@ucalgary.ca

Milk, cheese, and butter are common food items in the average Canadian's diet. They provide much of the daily servings of fats, proteins, vitamins, and minerals to keep us healthy. Milk production is also one of Canada's most important agricultural sectors in seven out of ten provinces. Canada prides itself on its high standard and quality of milk. Bovine mastitis is a disease caused by a bacterial infection in the udders of milk-producing cows, which leads to inflammation and lower qualities and quantities of milk produced. *Staphylococci* bacteria (bacterial group) infections are commonly associated with Bovine mastitis. *Staphylococcus chromogenes* is the most found species in cases of subclinical mastitis (a less intense, more chronic type of bovine mastitis). Our goal is to understand what genes in *S. chromogenes*' DNA are the most relevant in infecting and multiplying in cow udders. We can do that by first deleting random genes in *S. chromogenes*, thus creating many distinct mutants. Then we will test those mutants for virulence and survivability in an udder environment. By sequencing the DNA of the mutants before and after putting them through the udder environment, we can compare which genes were important in the mutants' ability to infect and adapt to the environment. These genes will give us insight into how *S. chromogenes* spreads and how we might be able to stop it from spreading, hence ensuring the future of high-quality Canadian milk and increasing milk production.

Take home message: This research will be essential to scrutinizing the significant virulence factors involved in the udder-adapted *S. chromogenes*. By creating random mutants and then testing them in an udder environment, we can pinpoint important virulent genes to develop a solution to lower the impacts of bovine mastitis.

Histology and kinetics of IgG transport in the neonatal bovine small intestine during the first 24 hours of life

R.L. Hiltz¹, D. Vine¹, D.R. Barreda¹, A.H. Laarman¹

¹Department of Agricultural, Food, and Nutritional Science, University of Alberta, T6G 2R3, Edmonton. Email: rhiltz@ualberta.ca

At birth bovine calves require absorption of colostrum to obtain transfer of passive immunity. Relatively little is known about the location and kinetics of immunoglobulin transport in the bovine neonate. This study focused on the effect of time after colostrum feeding on IgG transport kinetics and histological features in bovine small intestine in the first 24 hours of life. Holstein-Angus calves (n=30) were assigned to one of five harvest times after birth (1.5, 6, 12, 18, or 24hrs of life) and all except 1.5 hr calves were fed colostrum replacer within 1 hour of life. At harvest, a blood sample was taken for serum IgG analysis and segments of the small intestine were taken for histological analysis and for Ussing chamber experiments. The mucosal buffer in the Ussing chamber contained 120 mg/mL IgG and 10 mg/mL biotinylated IgG (B-IgG); serosal appearance of IgG and B-IgG were measured for 3 hours. Additionally, tissue from harvest was analyzed via periodic acid-Schiff stain and size and abundance of PAS positive vesicles were measured. Serum IgG peaked at 12 hrs (1,314 mg/dL IgG, $P<0.001$) and remained constant thereafter. The site of maximal IgG absorption was distal jejunum and it was greatest at 6 hrs of life (6 hr 18.6 ± 8.52 ; 12 hr 3.22 ± 6.19 ; 18 hr -0.43 ± 4.46 ; 24 hr 5.45 ± 5.05 mg/hr x cm²). Histologically, vesicle density was highest in 12 hr calves ($P<0.001$; 6hr 9.59 ± 0.42 , 12hr 13.58 ± 0.59 , 18hr 4.3 ± 0.46 , 24hr 7.8 ± 0.46 vesicles/villi. Vesicle size increased with time ($P<0.001$) was different per tissue type ($P<0.01$), with an interaction of time x tissue type ($P<0.01$). IgG flux indicated maximal IgG absorption occurred at 6 – 12hrs of life; vesicle parameters indicated that jejunum may be the site maximal absorption.

Take home message: Feeding colostrum early allows natural absorptive processes to occur to their maximum capacity; by 6 hours of life, some physical and physiological traits of absorption are already peaking.

Effects of ruminal short-chain fatty acids and pH on performance and hindgut fermentation of pre-weaned dairy calves

M. H. P. M. Narciso*, A. R. Wolfe, R. R. E. Uwiera, A. H. Laarman
Dept. Agricultural, Food and Nutritional Science, University of Alberta

While the importance of pH and short-chain fatty acids on rumen development are well-known, their impact on the intestine is unclear. We investigated the effects of ruminal SCFA concentrations and pH on calves' performance and hindgut fermentation. Holstein bull calves (n=32) were individually housed and fed milk replacer (900g/d) twice daily and calf starter *ad libitum*. At 10 ± 3 days of life, the rumens were fistulated and cannulated. On days 21, 35, and 49, feces were sampled to calculate apparent total tract digestibility (ATTD), digesta pH, as well as SCFA, BCFA, and lactic acid concentrations. Afterward, the rumen was evacuated and washed for 4h with one of four treatment buffers, assigned in a 2×2 factorial arrangement of high or low SCFA (285 vs. 10 mM) and high or low pH (6.2 vs. 5.2). The four treatment groups were: High SCFA, high pH (HS-HP); high SCFA, low pH (HS-LP); low SCFA, high pH (LS-HP); and low SCFA, low pH (LS-LP). After completion of rumen wash on d49, calves were harvested, and the tissue weight, length, and digesta pH of the rumen, cecum, colon, and rectum were recorded along with the digesta pH of duodenum, jejunum, and ileum. Data were analyzed with main factors as fixed effects and repeated measures for weekly measurements. Treatment and age did not affect ATTD, feed intake, body weight, and hindgut length and weight. In the duodenum, jejunum, and ileum, HS-HP had a greater digesta pH than LS-HP (P = 0.05, P = 0.04, P < 0.01, respectively). In comparison, only the high SCFA groups had a greater digesta pH in the colon and rectum (P < 0.01) and tended to have the same effect in the cecum digesta pH (P = 0.06). Colonic acetic acid (P = 0.05) and fecal lactic acid (P < 0.01) concentrations were lowest in the HS-LP group. Fecal SCFA and BCFA increased on d35 (P < 0.01). In summary, 4 hours of buffer infusion in the rumen did not change feed intake, body weight, ATTD, and hindgut weight and length. However, hindgut digesta organic acid concentrations and pH were changed by ruminal infusion.

Take home message: changes in the rumen environment can affect the hindgut fermentation in pre-weaned dairy calves.

Genetic engineering of a mycobacteriophage such that it is a better candidate for phage therapy against *Mycobacterium avium* subsp *paratuberculosis*

Natali Shafer
University of Calgary. Email: natali.shafer1@ucalgary.ca

Bacteriophages, viruses that infect bacteria, could be allies in our fight against Johne's disease. This disease has no effective treatments nor any completely protective vaccines. In addition to animal welfare concerns, it is a major cause of economic losses in the meat and dairy industries in Alberta and around the world. The infection is caused by a bacterium called *Mycobacterium avium* subsp. *paratuberculosis* (MAP). The De Buck laboratory has already tested the efficacy of using bacteriophages as a preventative treatment for this disease in an experimental infection trial. Calves were given a cocktail of nine different bacteriophages along with being exposed to MAP. The results of that trial indicated that the phages provided near complete protection against any of the calves developing Johne's disease after exposure, compared to calves that did not receive the phage cocktail. To conclude the trial, the calves were tested for any phages that remained in their digestive tracts long after the last time the cocktail was administered. Building on these advancements, I will be sequencing the genomes of phages that were found at the end of the trial to try to elucidate the reasons why these species persisted over others. The result of the sequencing is expected to result in a genome map of each phage and an analysis of persistent phages. I will then use the latest techniques to bioengineer these phages so that they adhere to the standards that are set for most phage applications in the agriculture sector. Phage bioengineering may help bring us closer to a future in which the development of Johne's disease can be prevented before it even has a chance to establish in calves.

Take home message: A cocktail of different viruses that infect bacteria (phages) were administered in a calf trial by the De Buck Laboratory and successfully prevented the establishment of Johne's disease. Next, the viruses will be bioengineered to improve their suitability for further explorations in phage therapy that aims to prevent Johne's disease establishment in calves.

Herd-level prevalence of bovine leukemia virus, *Salmonella* Dublin and *Neospora caninum* in Alberta dairy herds using ELISA on bulk tank milk samples

Waseem Shaikat^{1*}, Ellen de Jong¹, Kayley McCubbin¹, Marit Biesheuvel¹, Frank van der Meer¹, Jeroen De Buck¹, Guillaume Lhermie¹, David Hall¹, Kristen Kalbfleisch¹, John Kastelic¹, Karin Orsel¹, and Herman Barkema¹

¹Faculty of Veterinary Medicine, University of Calgary. *Email: waseem.shaikat@ucalgary.ca

For effective disease control, up-to-date prevalence estimates are needed. The objective of this study was to estimate herd-level prevalence of bovine leukemia virus (BLV), *Salmonella* Dublin, and *Neospora caninum* in Alberta dairy herds. Bulk tank milk samples from all Alberta farms were collected 4 times, in Dec 2021, and Apr, Jul, and Oct 2022, and tested for antibodies against BLV, *S. Dublin*, and *N. caninum* using ELISAs. Herd-level apparent prevalence was calculated, and the association of prevalence with region, herd size, herd type, and milking system type was determined using mixed effect modified Poisson regression. Prevalence of BLV was 89.4, 88.7, 86.9 and 86.9% in Dec, Apr, Jul, and Oct, respectively, whereas *S. Dublin* prevalence was 11.2, 6.6, 8.6, and 8.5%, and *N. caninum* prevalence was 18.2, 7.4, 7.8, and 15.0%. For BLV, *S. Dublin* and *N. caninum*, a total of 91.7, 15.6, and 28.1% of herds, respectively, were positive at least once. Compared to the north, central Alberta had a 1.13 times higher prevalence of BLV-positive herds, whereas south Alberta had 2.6 times higher prevalence) of herds positive for *S. Dublin* antibodies. Furthermore, central and south Alberta had a 2 times lower prevalence of *N. caninum*-positive herds compared to the north. Hutterite herds were 1.13 times more frequently BLV-positive but more than 2 times less frequently *N. caninum*-positive. Large herds (>7,200 L/day) were 1.1 times more often BLV-positive, whereas small herds (\leq 3,600 L/day) were 3.2 times more often *N. caninum*-positive. Moreover, *N. caninum* prevalence was 1.6 times higher on farms with conventional milking systems than automated milking systems.

Take home message: These results provide up-to-date information of the prevalence of these infections that will help in devising evidence-based disease control strategies.

Effect of SCFA concentration and pH on health and hematology in pre-weaned Holstein dairy calves

Author: A. Wolfe^{1*}, M. H. Paez Martins Narciso¹, R. R. E. Uwiera¹, A. H. Laarman¹

Dept. Agricultural, Food and Nutritional Science, University of Alberta¹. Email: arwolfe@ualberta.ca

Optimizing rumen development is key for preparing calves for weaning, however, the impact of the physiological development of the rumen on calf health and stress is unclear. This study investigated the effects of ruminal SCFA concentration and pH and their interaction on health parameters in dairy calves. Holstein calves (n = 32), housed individually on rubber mats, were fed milk replacer (26% CP, 18% fat; up to 900 g/d) twice daily, and calf starter (18% CP) and water ad libitum. At 10 \pm 3 d of life, calves were ruminally cannulated. One week after surgery, calves were blocked by initial body weight and randomly assigned in a 2 x 2 factorial arrangement of treatments of SCFA concentration (10 vs. 285 mM) and pH (5.2 vs. 6.2), yielding four treatment groups: low SCFA, low pH (LS-LP), high SCFA, low pH (HS-LP), low SCFA, high pH (LS-HP), and high SCFA, high pH (HS-HP). On weeks 3, 5, and 7, calves underwent a 4-h washed reticulorumen procedure with a physiological buffer containing one of the four treatments. Daily intakes of milk replacer and calf starter were recorded. Body weight, clinical health measures, blood hematology, and fecal scores were obtained weekly. Grain intake and ADG both increased as the calf aged regardless of treatment. Fecal score decreased as the calf aged. Low rumen pH increased respiration by 4.7 bpm. No difference was detected in body core temperature by treatment over time. From wk 5 to wk 7, white blood cell counts decreased in the LS-LP group but increased in the HS-LP group. No differences were detected in calf red blood cell counts, platelet counts, cortisol levels and beta-hydroxybutyrate by treatment or age. Hemoglobin and hematocrit percent increased in the HS-LP groups during wks 5 and 7. Haptoglobin decreased by 0.2 mg/ml every two weeks regardless of treatment. Overall, rumen environment does not impact clinical health but does impact some hematological markers short term.

Take Home message: These preliminary results demonstrate that calves are resilient to changes in the rumen environment, even with a pH as low as 5.2; a pH that adult cows would not be able to tolerate and would in fact cause severe ruminal acidosis.

Effect of dietary supplementation with bovine derived *Bifidobacterium longum* spp. *longum* and resistant potato starch on the health and growth of neonatal calves

Xiang Wu¹, Philip Griebel², Nilusha Malmuthuge³, Leluo Guan^{1*}

¹Faculty of Land and Food Systems, University of British Columbia, Vancouver, BC; ²School of Public Health, University of Saskatchewan, Saskatoon, SK; ³Agriculture and Agri-Food Canada, Lethbridge, AB. *Corresponding email: leluo.guan@ubc.ca

Probiotics have been reported to improve health, but the studies are controversial due to the lack of host-specific products and limited understanding of their mode of action. This study assessed the impact of supplementation of probiotics, prebiotics and synbiotics on growth performance, the incidence of diarrhea and lung health when calves were fed a sub-optimal amount of colostrum. Forty-five newborn calves were randomly allocated to five treatment groups (n=9) for a 5-week period: four groups received 25% of the recommended dose of commercial colostrum replacer (1L), while one group received the recommended amount (4L). The group receiving the 4L of colostrum (PC) and one group receiving 1L of colostrum received a placebo (NC), and the other three groups received either a cocktail consisting of four strains of bovine-derived *Bifidobacterium longum* spp. *longum* strains B3, B5, B8, B15 (isolated from rectal and colonic contents of neonatal calves) (10e9 CFU/day) (PRO), resistant potato starch (80g/day) (PRE), or both bifidobacterial strains (10e9 CFU/day) and resistant potato starch (80g/day) (SYN) from day 2 to 14 post-partum. Initial (day 1) and final body weights (day 35) were recorded for the calculation of average daily gain (ADG). Lung lesion scores at day 35 were obtained by visual inspection of lung tissue. There was no significant difference in ADG (P=0.65), the incidence of diarrhea (P=0.46) among the five groups. The tendency of 86.6% and 87.2% of lower likelihood of developing lung lesions compared to NC was observed in PRO (P=0.06) and PRE (P=0.06), respectively.

Take home message: The lung lesion scores showed evidence that pre- and probiotics benefit lung health, and further investigation is needed to explore their efficacy at the doses when neonatal calves receive a sub-optimal quantity of colostrum.

Effect of oral Ca boluses on serum Ca concentration, health events, milk yield, activity and rumination behavior in Holstein cows

M.G. Colazo^{1,2}, K. Macmillan¹, A. Behrouzi¹, M. Gobikrushanth³

¹University of Alberta; ²Leduc Farm Animal Hospital; ³University of Queensland; E-mail: colazo@ualberta.ca

Holstein cows (with one or more previous lactations) fitted with a collar-mounted automated activity monitoring (AAM) system (Heftime®, SCR Engineers) were blocked by previous 305 ME milk yield, parity and day of calving and assigned randomly to receive no treatment (Control; n=23) or two 50 g oral Ca chloride boluses (RumiLife® CAL24™; n=23) within 6 h after calving. Blood samples were collected at treatment or within 6 h after calving (SCa1) and 24 h later (SCa2) to determine total serum Ca concentrations at the Animal Health Laboratory (University of Guelph). Cows were observed for health disorders by farm personnel. Rumination and activity behavior were monitored continuously by the AAM system for 21 d after calving and milk yield recorded daily up to 8 wks after calving. Data were analyzed using PROC MIXED in SAS. SCa1 did not differ between treatment groups, but SCa2 was greater in treated cows compared to Control (2.0 ± 0.06 versus 1.7 ± 0.06 mmol/L; $P=0.009$). Lactation number negatively affected SCa1 and SCa2, but there was no interaction between lactation number and treatment on serum Ca concentrations. Health events were recorded in 9 treated and 10 Control cows with 1 and 4 cases of clinical hypocalcemia for treated and Control cows, respectively. Average daily activity was reduced by 2.8% in cows given oral Ca boluses compared to Control cows, however, rumination (573.2 ± 3.6 min) and milk yield (46.4 ± 0.5 kg) did not differ between treatment groups.

Take home message: Administration of oral Ca boluses increased total serum Ca concentrations 24 h after treatment and numerically reduced the cases of clinical hypocalcemia. Although, oral Ca boluses treatment was associated with a small reduction in activity, it did not affect rumination time nor milk yield.

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Associating reproductive physiology and automated monitoring technologies to predict fertility of dairy herds: II. lactating Holstein cattle

R. Conceicao^{1*}, A. Madureira², J. Marques¹, J. Maciel³, J. Denis-Robichaud¹, S. Moore¹, C. Baes⁴, R. Cerri¹

¹Faculty of Land and Food Systems, University of British Columbia, Canada; ²Ridgetown Campus, University of Guelph, Canada; ³Faculty of Veterinary Medicine, Rural Federal University of Pernambuco, Brazil; ⁴Centre of Genetic Improvement of Livestock, University of Guelph, Canada. Email: rodrigo.conceicao@ubc.ca

The display and intensity of estrous expression, measured by automated activity monitors (AAM), have been associated to improve fertility of lactating Holstein cattle. Although the exact mechanism controlling intensity of estrus in dairy cows remains elusive, progesterone (P4) concentrations prior to estrus have been shown to be positively associated with intensity of estrous expression. However, the unanswered questions were: Would be possible to manipulate the intensity of estrus and thus fertility by controlling P4 concentration before estrus? Could AAM data be used to refine fertility indexes of genetic selection programs used in dairy cattle? First, we evaluate if different exposure of P4 prior to estrus would impact the intensity of estrous measured by AAM. Additionally, we evaluate the P4 association on luteinizing hormone (LH) and prostaglandin metabolite (PGFM) profiles. The second study was conducted to evaluate the association of intensity of estrus and the LH profile following gonadotropin-releasing hormone (GnRH) administration at the supposed time of artificial insemination. In the first study, elevated P4 concentration prior to estrus was associated to greater intensity of estrous expression and lower PGFM profile. Although no differences in LH concentration between different P4 concentration were observed, the peak of LH occurred earlier for cows with lower P4 concentration compared to elevated P4. In the second study, there was an increase in LH concentration following GnRH administration, but no association of intensity of estrus on LH profile was observed independently of GnRH administration. Next steps include refine estrus data to improve reproductive indexes used in genetic selection programs.

Take home message: The modulation of estrous expression through manipulation of physiological parameters could provide insights on the underlying physiology of fertility traits used in genetic selection programs.

The potential for genetic selection against Bovine Spastic Syndrome (Crampy) in Canadian Holstein dairy cattle

Gabriella Condello¹, Isis Hermisdorff¹, Colin Lynch¹, Christina M. Rochus¹, Flavio S. Schenkel¹, Brian J. Van Doormaal², Filippo Miglior^{1,2}, Christine F. Baes^{1,3}

¹Centre for Genetic Improvement of Livestock, Department of Animal Biosciences, University of Guelph, Guelph, ON, Canada, ²Lactanet, Guelph, ON, Canada, ³Institute of Genetics, Department of Clinical Research and Veterinary Public Health, University of Bern, Bern, 3001, Switzerland. Email: gcondell@uoguelph.ca

Bovine spastic syndrome (Crampy) is a neuromuscular disorder characterised by the involuntary hyperextension of the hindlimb and seen when affected cattle attempt movement. The disorder typically affects cattle aged three years and older, is detrimental to cattle welfare and is increasing in prevalence among Canadian dairy herds, which is a cause for concern in the industry. The objective of this study was to estimate genetic parameters of Crampy in Canadian Holstein dairy cattle to assess the potential for genetic selection. Lactanet Canada (Guelph, ON, Canada) provided data from 678 dairy herds, where producers recorded at least one case of Crampy (1,952 cases). The average within-herd prevalence of Crampy was 4.7% and the overall prevalence of Crampy within this study was 3.6%. Crampy was evaluated as a binary phenotype using a univariate threshold animal model. The liability scale heritability was estimated to be 0.47 ± 0.039 , which corresponds to a heritability of 0.085 on the observed scale. This estimated observed scale heritability is similar to a recent estimate of 0.074 reported in literature, based on a prevalence of 3.6%. These results indicate that reducing Crampy incidence through genetic selection is feasible and the trait could be considered for inclusion in Canadian national genetic evaluations.

Take home message: Crampy is a neuromuscular disorder that causes pain and stress through muscle spasms when cattle transition from a lying position. Genetic selection is a tool that could help reduce Crampy incidence in Canadian herds.

Classifying Holstein dairy cows by body condition score and the effects on dry matter intake and milk production during the late dry period and early postpartum period

K. Dekraker¹, M. Boeremyn¹, S. Cartwright¹, S. Jantzi¹, A. Pineda¹, C. Villot², and M. A. Steele¹.
University of Guelph¹; Lallemand SAS, France². Email: kdekrake@uoguelph.ca

Classifying cows by body condition score (BCS) prepartum and through the course of lactation may be a predictor of reduced dry matter intake (DMI) and milk production in the early postpartum period. The aim of the study was to determine if there is a connection between BCS, DMI, milk yield and milk components. Fifty multiparous (MP) and 30 primiparous (PP) Holstein cows were BCS weekly from -4 to +10 wk relative to calving were classified as high (>3.5; H), ideal (2.75-3.25; I), and low (<2.75; L). Milk yield and DMI were recorded daily. Milk samples were collected once weekly until d70 after calving and analyzed for components. Prepartum DMI did not differ between H, I, and L. Postpartum DMI was lowest in H, intermediate in I and highest in L (15.2, 19.9, and 21.3 kg/d; $P < 0.01$). Milk yield was lowest in H, intermediate in I, and highest in L (31.1, 36.7, and 39.9 kg/d; $P < 0.01$), but 3.5 % fat corrected milk (FCM) did not differ between H, I, and L. Milk fat content was greater in H compared to L (4.73, vs 4.11%; $P = 0.05$) and no differences were observed between H and I or L and I. Protein content was greater in H and I compared to L (3.41, and 3.19, vs. 2.98%; $P = 0.04$). Yields of milk fat and protein were similar for H, I, and L. Milk fat and protein content were similar for MP and PP cows, but MP cows had greater yields of milk fat (1.85 vs., 1.35 kg/d; $P < 0.01$) and protein (1.33 vs., 1.01 kg/d; $P < 0.01$). Results from our study showed that BCS impacts pre- and postpartum DMI and milk production responses during the early postpartum period of Holstein cows.

Take home message: BCS of Holstein cows in late gestation and early postpartum has an impact on DMI and milk production and should be considered in management decisions.

Effect of oat variety and oat type (feed-type vs milling-type) with multi-year samples on nutrient supply from rumen degradable and undegradable protein and carbohydrate fractions in western Canada

Ganqi Deng, María E. Rodríguez Espinosa, David A. Christensen, H. (Bart) Lardner, 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

The objectives of this study were to investigate the effects of oat variety and oat type (feed-type vs milling type) on nutrient supply from rumen degradable and undegradable protein and carbohydrate fractions. The recent oat varieties in this study were provided by Crop Development Center, including Arborg (Milling), Haymaker (Forage type), Nasser (Feed-type), and Summit (Milling type) which were grown and harvested at the university crop research fields for three consecutive years. The nutrient supply from rumen degradable and undegradable protein and carbohydrate fractions were evaluated with the Cornell Net Carbohydrate and Protein System. The experiment design was a RCBD. The data was analyzed using mixed model procedure of SAS with the oat varieties as a fixed effect and the years as a random block effect. Multi-treatments comparison was used Tukey methods. The comparison between milling-type oat and feed-type oat was used orthogonal contrast of SAS. The results showed that the oat varieties had significant differences ($P < 0.05$) in total rumen degradable protein supply (TRDP, range from 9.2 to 11.1 %DM), total rumen undegradable protein supply (TRUP, range from 5.5 to 6.5%DM), but no significant differences in total rumen degradable carbohydrate supply (TRDC, average 46.9%DM), total rumen undegradable carbohydrate supply (TRUC, average 31.4%DM). Compared between the milling-type oat and feed-type oat, there was no significant difference in TRDP, TRUP, TRDC and TRUC.

Anogenital distance as a novel trait for enhancing fertility in Canadian Holsteins

Gabriella Dodd¹, Filippo Miglior^{1,2}, Flavio S. Schenkel¹, Tony C. Bruinje³, Mohanathas Gobikrushanth⁴, Jennifer Carrelli⁵, Masahito Oba⁵, Divakar J. Ambrose⁵, Christine F. Baes^{1,6}

¹Centre for Genetic Improvement of Livestock, Department of Animal Biosciences, University of Guelph, Guelph, ON, Canada; ²Lactanet, Guelph, ON, Canada; ³Department of Population Medicine, University of Guelph, ON, Canada; ⁴School of Veterinary Science, University of Queensland, Gatton, Australia; ⁵Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB, Canada; ⁶Institute of Genetics, Vetsuisse Faculty, University of Bern, Bern, Switzerland. Email: gdodd@uoguelph.ca

Fertility poses challenges in global dairy programs but is crucial for industry sustainability. Slow improvement of reproductive performance shifted industry focus to cow fertility, but current fertility indicator traits have low heritability estimates and are highly susceptible to environmental influences. Anogenital distance (AGD), a morphological trait reflecting prenatal androgen exposure, has shown promise as a fertility indicator in various species. Physiological studies have demonstrated a favorable relationship between short AGD and positive reproductive outcomes in females. This study assessed the feasibility and efficacy of incorporating AGD into genetic selection programs for dairy cattle. We investigated the genetic basis of AGD using a dataset of 4,985 Holstein cows and heifers across 20 farms in Canada. AGD records were normally distributed, with a mean value of 126.57 ± 13.79 mm. Our analysis using a single-trait animal model estimated a heritability of 0.40 ± 0.04 . The reliability of estimated breeding values (EBV) was 0.82 for proven sires (≥ 30 daughters). Results suggest that AGD is a moderately heritable trait in Canadian Holsteins and sire EBV can be reliably predicted. This study represents an initial exploration of AGD as a fertility indicator trait for dairy cows, but results are promising and encourage further research into its application in breeding programs. Incorporating AGD into genetic selection could significantly contribute to enhancing overall herd efficiency.

Take home message: This study suggests that anogenital distance can be genetically selected for the improvement of female fertility in dairy cattle.

The effects of pellet starch concentration and allocation amount for Holstein cows in early, mid, and late lactation in an automatic milking system

S. C. Dondé¹, A.J. Schwanke², T. DeVries², R. C. da Silva³, G. B. Penner^{1*}

¹Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, SK, Canada S7N 5A8; ²Department of Animal Biosciences, University of Guelph, Guelph, ON, Canada N1G 2W1; ³Department of Animal Science, Luiz de Queiroz College of Agriculture, Piracicaba, SP, Brazil. Email: greg.penner@usask.ca

This study evaluated the effects of pellet starch concentration and amount of pellet delivered in an automated milking system (**AMS**) on feed intake and milking characteristics. Twenty-four Holstein cows in early (85 ± 25.7), mid (185 ± 35.1) or late (290 ± 69.5 days in milk; **DIM**) lactation were housed in a free-stall barn with feed-first guided traffic flow AMS. Treatments included pellets with high (**HS**; 34%DM) or low (**LS**; 24%DM) starch with high (**HA**; 6kg/d DM) or low (**LA**; 2kg/d DM) quantities allocated within a 4×4 Latin square. Pellet starch did not affect the amount of pellet consumed, but HA cows consumed more than LA (4.3 vs 1.8 kg/d; $P < 0.01$). Relative to LA, HA cows left 0.4 kg/d more pellet in the AMS ($P < 0.01$) and ate 1.2 kg/d less PMR ($P = 0.05$). However, total DMI was 1.3 kg/d greater for HA than LA ($P = 0.05$). Pellet starch and DIM did not affect PMR intake or DMI. Milking frequency was not affected by pellet starch or DIM but HA cows tended have to greater milking frequency (2.7 vs 2.6 no./d; $P = 0.06$) over LA. Milk yield (42.6 L/d) was not affected by pellet starch, amount, or DIM. Compared to LS, HS decreased milk fat concentration (3.9 vs 4.1% ; $P < 0.01$) and providing the HA reduced milk fat concentration (3.9 vs 4.1% ; $P < 0.01$) over LA; however, pellet starch and the allocation did not affect fat yield ($P \geq 0.15$ average = 1.7 kg/d). True protein yield was not affected.

Take home message: Feeding a high starch AMS pellet may reduce milk fat concentration. Feeding higher amounts of pellet in the AMS may reduce PMR intake while increasing total DMI. HA of pellets may also increase attendance at the AMS; however, there was no effect on milk yield and a reduction in milk fat concentration.

The longitudinal effects of topical treatment on chronic and recurring cases of digital dermatitis

C. S. Gammariello, A. P. Dias, J. De Buck; University of Calgary; corienne.gammariello@ucalgary.ca

Digital dermatitis (DD) is a polymicrobial, infectious disease of dairy cattle that compromises animal welfare and productivity through the development of painful, ulcerative heel lesions. The presence of DD in a herd is associated with lameness, extra veterinary costs, and reduced milk production leading to major concerns within the dairy industry. Oxytetracycline is a common topical antibiotic used to treat DD but lesions often persist after treatment. It is unclear if this is due to a failure of oxytetracycline treatment to eliminate DD-associated bacteria or if treated lesions are reintroduced to pathogens from the environment. This study will aim to investigate changes in the bacterial populations of DD lesions after topical treatment of oxytetracycline to better understand cases of chronic and recurrent DD in dairy cattle. Forty Holstein cows from 4 local, Albertan farms with M2 DD lesions will receive topical lesion treatment of oxytetracycline powder. Treated lesions will be repeatedly sampled from using cotton swabs for a total of 18 timepoints across a year. Swabs will be analyzed using qPCR methods to quantify DD-associated bacteria such as *Treponema*, *Porphyromonas*, *Fusobacterium*, and *Mycoplasma* species. Microbiome analyses will also be performed to assess and compare variations in bacterial populations across time.

Take home message: The potential research outcomes of this study include indication of which DD bacteria persist after treatment and are associated with chronic, recurring DD lesions. We hope the implications of this study will contribute to the optimization of future DD drug treatments.

Development of prairie environment friendly and value-added pellet products to mitigate ruminant methane: Effect of hydrolysable tannin as phytochemical feed additive on total digestible nutrient and energy values in beef and dairy cattle

Taufiq Hidayat, María E. Rodríguez Espinosa, Rex Newkirk, H. (Bart) Lardner, 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: Professor & Ministry of Agriculture Strategic Research Chair; Tel: +1 (306)-966-4132; peiqiang.yu@usask.ca

To date, there were no study on effects of blend pellet co-products from bio-fuel/bio-oil processing with low grade of peas (or pea/lentil screenings in combination with hydrolysable tannins at different levels. This research program aims to develop prairie environment friendly and value-added pellet products to mitigate ruminant methane. The objectives of this study were to study effect of plant extracted hydrolysable tannin (PEHT) as phytochemical feed additive at different dosage levels on total digestible nutrient, energy values in beef and dairy cattle and Feed milk value based on Net energy for lactation (FMV_{NEL}). Four levels of PEHT (0% (control), 2%, 4%, 6%) were added to two different feeds with different ratios of canola meal and pea (CP1: 50:50 and CP2: 70:30) which were used to make blend pellet product at Canadian Feed Research Center (CFRC). The total digestible nutrients and energy values were determined using NRC summary approach (NRC, 2001). The experimental design was a CRD with the dosage level and blend pellet product as fixed effects. Polynomial contract was used to determine linear and quadratic relationship between dosage level and nutritional value. The results showed that adding PEHT had quadratically effect on total digestible crude protein (tdCP), but it did not significantly impact tdNDF, tdNFC, tdFA, total digestible nutrient (TDN), NE for lactation, NE for growth, and NE for maintenance as well as FMV_{NEL}.

Take home message: Compared with two different blend pellet products CP1 vs CP2, it showed that CP1 had significantly higher TDN (77.2 vs 75.2 %DM), tended to be higher in NE for lactation, NE for growth, NE for maintenance and FMV_{NEL}.

Evaluation of the newly developed value-added blended fat stimulated feed product (bfsfp): Comparison with commercial protein and energy feeds in total digestible nutrients and energy profile

Umair Ihsan, Luciana Prates, H. (Bart) Lardner, Rex Newkirk, María E. Rodríguez Espinosa, 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: Professor & Ministry of Agriculture Strategic Research Chair; Tel: +1 (306)-966-4132; peiqiang.yu@usask.ca

The objectives of this study were to compare total digestible nutrients energy values of commercial protein and energy products with newly developed value-added blended fat stimulated feed product (called BFSFP) and Feed Milk Value based on net energy for lactation (FMV_{NEL}). Three-batches samples of the newly developed value-added blended fat stimulated feed products BFSFP1, BFSFP2 and BFSFP3 were developed with the Saskatchewan feed industry. Three samples of barley grain (n=3) and canola meal (n=3) were obtained from Canadian Feed Research Center (CFRC). The total digestible nutrients and energy values were determined using NRC summary approach. The treatment design was a one-way structure. The experimental design was a CRD with feed treatments as a fixed effect. The results showed that compared with commercially available energy-rich and protein-rich feeds, the newly developed BFSFP was lower in tdNFC than barley grain ($P<0.05$), but similar to canola meal, higher in tdCP than barley grain but lower than canola meal ($P<0.05$), highest in tdNDF and tdFA ($P<0.05$). The BFSFP had higher ($P<0.05$) TDN (73.67% DM) than canola meal (66.30 %DM) but lower ($P<0.05$) than barley grain (84.97%DM). As to energy value, BFSFP had no significant difference in NE for lactation when compared to barley grain and canola meal (1.80 vs 1.93 vs. 1.69 Mcal/kg DM, $P>0.05$). However, BFSFP had similar in NE for growth (1.29 Mcal/KD DM) when compared to canola meal (1.29 vs. 1.20 Mcal/kg DM, $P>0.05$) but lower than barley (1.29 vs 1.42 Mcal/kg DM, $P<0.05$).

Exploring dairy farmer well-being in the context of animal health and welfare: A One Welfare perspective

A. Le Heiget¹, H. Tambadou¹, B. Zwick¹, V. Fraser-Celin², B. Hagen², A. Jones², J. Kinley¹, E. Pajor³, J.C. Plaizier¹, K. Ominski¹, and M. King¹.
¹University of Manitoba; ²University of Guelph; ³University of Calgary; meagan.king@umanitoba.ca

Dairy farmers are faced with many challenges that come with caring for animals, a phenomenon of interest to the growing concern for the mental health of farmers. To adequately address the needs of dairy and livestock farmers, a deeper understanding of the interconnections between farmer well-being, technology, and animal health and welfare is needed. The objective of this study was to explore dairy farmer well-being in the context of animal health and welfare. An interview guide was created in collaboration with industry stakeholders, academics, and dairy farmers, and was used by the lead author (ALH) to conduct semi-structured interviews with 30 dairy farmers from Western Canada and Ontario. Farmers were selected to represent various age groups, genders, housing systems, and milking systems. The average length of interviews was 77 minutes. The topics discussed included relationships and labour, technology, well-being, animal health, mental health resources, and coping. Interviews transcripts were open-coded by 4 authors (ALH, BH, AJ, VFC) to create a codebook. Preliminary themes indicate that dairy farmer well-being is interconnected with the herd health/welfare and macro- and micro-environments. For example, when farmer well-being is put on the 'backburner' to care for animals, the farmers' physical health and mental health may be negatively impacted; thus, if they are not able to function at their full capacity, this may lead to compromised animal care, further posing risks to animal health and welfare, which is directly linked to production.

Take home message: Emphasis is often placed on the animals within food systems rather than the farmers' that care for them. This study highlights a need for targeted approaches to bring awareness to the well-being of dairy and livestock farmers, and to ensure there are resources available with adequate (agri)cultural competency to support the farmers who produce our food.

A comprehensive evaluation of the genetic background of rumination time in first-lactation dairy cows

L. Lopes¹, F. Schenkel¹, D. Tulpan¹, C. Baes^{1,2}

¹Centre for Genetic Improvement of Livestock, University of Guelph, 50 Stone Road E, N1G 2W1, Guelph, Ontario, Canada, ²Institute of Genetics, Department of Clinical Research and Veterinary Public Health, University of Bern, Bern, 3001, Switzerland e-mail: llopes@uoguelph.ca

The Canadian dairy cattle industry is committed to reducing greenhouse gas emissions. Rumination time (RT) has shown potential as a proxy for several traits, including enteric methane emission (ME) of dairy cattle. However, despite its relevance, little is known about the genetic background of RT. Moderate heritability estimates for RT support further investigation of its genetic architecture. Therefore, our objectives were to: (1) conduct a Genome Wide Association Study (GWAS), identify candidate genes and carry out Quantitative Trait Locus (QTL) enrichment analysis for RT; (2) assess the combined use of RT and milk mid-infrared spectra (MIR) data in machine learning algorithms for ME predictions. A total of 452 mid-first lactation Canadian Holstein cows were genotyped with a 50K panel. Single Nucleotide Polymorphism (SNP) effects were estimated using single-step genomic BLUP, and significant SNPs were identified after a chromosome-wise modified Bonferroni correction. Thirty-five SNPs and 37 genes were associated with RT, and 167 QTLs were enriched, linking RT to fat synthesis and deposition in milk and muscle. Gene Ontology and Kyoto Encyclopedia of Genes and Genomes terms showed that RT is related to synaptic functions. We also assessed the performance of different data sets for predicting ME using artificial neural networks, combining unprocessed or processed MIR data and RT (N = 423). The inclusion of RT did not increase the prediction ability of alternate data sets with or without the inclusion of MIR data. Our results indicate that RT seems to be a weak predictor of ME in dairy cows, but investigations with larger datasets should be carried out to confirm our results. Nevertheless, our findings offer insights into the genetic architecture of RT and enhance the understanding of its physiology.

Take home message: Rumination time is a polygenic trait that seems associated with milk fat production. However, rumination time seems to be a poor predictor of methane emission in dairy cows.

Kinematic metrics for pain as a negative affective state in dairy cows

E.R. Lowen, M.A. Ganley, H.J. Perez Marquez, and C.J. Bench

Department of Agriculture, Food and Nutritional Science, University of Alberta, Edmonton AB, T6G 2P5; bench@ualberta.ca

Identification of negative affective states, such as pain due to lameness, is important in ensuring good cow welfare. However, dairy cattle do not have expressive faces making affective state difficult to detect. The purpose of this preliminary study was to determine if infrared thermography (IRT) and 3D kinematics can be used for the detection of pain as a negative affect associated with lameness in dairy cows. Sixteen Holsteins were recorded once a week for three weeks; including eight healthy and eight lame cows (n=8 cows/treatment). Infrared images of the eyes, hooves and legs were recorded and kinematic markers were placed on important facial landmarks. Data was analyzed using the GLIMMIX procedure in SAS to compare the effect of lameness status on kinematic and IRT thermal metrics. Notably, lameness status had no significant effect on infrared eye temperature. However, significant differences in knee, fetlock, and coronary band temperatures were found between treatment groups. As such, temperature data alone using IRT does not appear to be able to detect pain as an affective state. In contrast, the use of facial kinematics demonstrated that the poll to jaw muscle distance differed significantly between lame and healthy cows. Specifically, the distance increased in lame cows indicating a drooping affect (Lame cows: left jaw 376.3 ± 5.26 mm $P < 0.01$; right jaw 371.7 ± 4.54 mm $P < 0.05$). In addition, the ear-poll-ear angle was significantly larger in lame cows (Lame: $103.6 \pm 1.13^\circ$; Healthy: $94.6 \pm 1.19^\circ$; $P < 0.01$) which indicates ear drooping. Overall, the kinematic results show that lame cows exhibited a consistent downward movement of both ears and facial muscles which serve as indicators of negative affect.

Take home message: Thermal IRT metrics can detect lameness but were unable to detect negative affect. Future IRT affect research should consider imaging of the entire face for indicators of flushing. 3D kinematics was able to detect changes in affective state through ear and facial muscle drooping.

Genetic selection for reducing dairy calf diarrhea and respiratory disease

C. Lynch^{1*}, F. S. Schenkel¹, F. Miglior^{1,2}, D. Kelton³, C. F. Baes^{1,4}

¹Centre for Genetic Improvement of Livestock, Department of Animal Biosciences, University of Guelph, Guelph, ON, N1G-2W1, Canada;

²Lactanet Canada, Guelph, ON, N1K-1E5, Canada; ³Department of Population Medicine, University of Guelph, Ontario, N1G-2W1, Canada;

⁴Institute of Genetics, Department of Clinical Research and Veterinary Public Health, University of Bern, Bern, 3001, Switzerland; email: clynch@uoguelph.ca

The dairy industry faces the challenge of maintaining and enhancing animal health standards. Genetic selection represents a valuable tool for achieving this goal. However, there has been limited exploration into the genetics of calf-hood diseases. To address this gap, our study aimed at assessing the present impact of two common dairy calf diseases on Canadian farms: respiratory problems (RESP) and diarrhea (DIAR). This involved examining incidence rates, estimating genetic parameters, and formulating industry recommendations. The producer-recorded calf disease data analyzed comprised of 69,695 Holstein calf disease records for RESP and diarrhea DIAR from 62,361 calves collected on 1,617 Canadian dairy herds from 2006 to 2021. Additionally, we explored two scenarios based on minimum herd-year disease incidence thresholds (1% and 5%) to highlight the influence of data filtering criteria on selection potential for RESP and DIAR. Heritability estimates for RESP and DIAR ranged from 0.02 to 0.06 across analyses. Genetic correlations between RESP and DIAR were found to range from 0.50 to 0.62, while correlations with production traits were low (0.03 to 0.08). Comparisons of sires based on estimated breeding values and observed daughter diseased incidence rates revealed that, on average, calves born to the bottom 10% of sires were 2.2 times more likely to develop DIAR and 1.8 times more likely to develop RESP.

Take home message: Genetic selection to improve calf health is possible. However, effective genetic evaluation requires industry outreach to emphasize the value of recording and standardizing data collection practices.

Associating reproductive physiology and automated monitoring technologies to predict fertility of dairy herds: I. Holstein heifers

J. Marques^{1*}, A. Boyle¹, R. Conceicao¹, A. Madureira², J. Maciel³, S. Moore¹, J. Denis-Robichaud¹, C. Baes⁴, R. Cerri¹.

¹Faculty of Land and Food Systems, University of British Columbia, Vancouver; ²Ridgetown Campus, University of Guelph, Ridgetown; ³Faculty of Veterinary Medicine, Rural Federal University of Pernambuco, Recife; ⁴Centre of Genetic Improvement of Livestock, University of Guelph, Guelph. Email: jessica.dossantosmarques@ubc.ca

The display and intensity of estrus behaviour, measured by automated activity monitors, have been linked to improved fertility of dairy cows and heifers. Although, the physiological mechanism driving the association between this behavioural feature and dairy cow fertility is yet to be determined, greater concentration of the hormone progesterone (P4) before estrus was associated with improved fertility and greater intensity of estrus in lactating cows. However, the unanswered questions were: is the association between P4 and intensity of estrus the same for heifers? Would be possible to manipulate the intensity of estrus and thus fertility by controlling P4 concentrations before estrus? Additionally, we questioned: could we add different features of estrous expression to indexes of genetic selection programs used in dairy cattle operations? Two experiments were conducted aiming to evaluate the association between P4 and intensity of estrus in Holstein heifers. The first study was conducted in a crossover design using single ovulating heifers and had as a secondary objective the evaluation of ovulation timing. The second experiment was done in superovulated heifers with embryo production and quality as secondary objectives. Greater P4 concentrations before estrus was associated with greater intensity of estrus in single ovulating heifers, but no effect on ovulating timing was found. Although P4 concentrations did not associated with intensity of estrus in superovulated heifers, the number of embryos produced was shown to increase as the duration and the intensity of estrus increased. Next steps include refine estrus data to improve reproductive indexes used in genetic selection programs.

Take home message: Progesterone and intensity of estrous expression could be implemented as important markers to refine fertility traits used in genetic selection programs.

Investigating the impact of beta-hydroxybutyrate concentrations on dairy cow behaviour and productivity for cows milked in robotic milking systems

S. Moore, J. Marques, R. Conceicao, 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 exponentially worldwide. Cows are free in these systems to milk more often and typically produce higher quantities of milk. The increase in energy required to support this production level has been linked to an increase in beta-hydroxybutyrate concentrations, indicative of prevalent illnesses such as subclinical ketosis (SCK). However, current thresholds of SCK were established primarily using cows milked in conventional milking systems (tie stalls and parlours). Therefore, the objective of this study is to further explore various beta-hydroxybutyrate concentrations (BHB), within robotically milked herds, to understand the impact on milking characteristics and cow behaviour in today's modern dairy industry. 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 days in milk (DIM). Blood samples were collected across the first 21 DIM, with blood analyzed cow-side for BHB. As this project is still ongoing, only preliminary results are available. Area under the curve (AUC) for each cow's BHB values throughout the first 21 DIM was calculated. For every 1 unit increase in AUC, milk yield increased by 0.9 kg/d, eating time decreased by 7.2 minutes/d, and rumination decreased by 7 minutes/d ($p=0.005$, $p=0.02$, $p=0.05$ respectively). The number of positive SCK tests and when they occurred was tested to determine the impact on daily milking characteristics and cow behaviour. Positive tests (BHB>1.0 mmol/L) occurring in week 3 postpartum (15-21 DIM) had the greatest impact on cow behaviour with a decrease in rumination on average by ~58 mins/d, and a decrease in eating time by ~70 mins/d ($p=0.001$, $p=0.004$, respectively).

Take home message: This research aims to help producers better understand the impact of BHB concentrations and SCK thresholds on the productivity, behaviour and health of their animals.

Effect of maturity stage on rumen degradable and undegradable subfractions of protein and carbohydrate of intercropping whole plant oat (*Avena sativa* cv. CDC Haymaker) with whole plant faba bean (*Vicia faba* cv. CDC Snowbird) as hay in ruminant livestock systems, evaluated with the updated CNCPS system

Carlene Nagy, Victor Guevara-Oquendo, David A. Christensen, H. (Bart) Lardner, 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: peiqiang.yu@usask.ca

The objectives of this study were to determine effect of maturity stage at harvesting on rumen degradable and undegradable subfractions of protein and carbohydrate of intercropping whole plant oat (*Avena sativa* cv. CDC Haymaker) with whole plant faba bean (*Vicia faba* cv. CDC Snowbird) as hay in ruminant livestock systems, evaluated with the updated CNCPS System. The oat and faba bean plant were intercropped and grown in three fields with a seeding ratio of 0.5 bushel of oat grain to 4 bushels of faba bean seeds per acre (or 18 kg of oat seed to 269 kg of faba bean seed per hectare). The intercropped forages were harvested at three growth stages: maturity stage 1 was harvested when the oat plants were in the inflorescence stage and the faba bean plants were in the flat pod stage; maturity stage 2 was harvested when the oat plants were in the milk development stage and the faba bean plants were in the milk pod stage; and maturity stage 3 was harvested when the oat plants were at the soft dough stage and the faba bean plants were in the late pod stage. In terms of protein subfractions, the results showed that the maturity stage affected ($P<0.05$) PA2 and PC fractions and but did not affect PB1 and PB2 ($P>0.05$). With increasing maturity stage, the PA2 reduced from 63.4 to 56.0 %CP. As to carbohydrate subfractions, the maturity stage only affected ($P<0.05$) CB1 and CA4 subfractions on %DM basis and but did not affect CB2, CB3 and CC subfractions. With increasing maturity stage, both CA4 and CB1 were increased from 10.4 to 18.2 % CHO and CB1 from 0.5 to 9.9% CHO respectively. In the CNCPS rumen degradable and undegradable fractions study, the results showed that the maturity stage affected ($P<0.05$) total TRDP and total TRDC without affecting total TRUP and total TRUC. With increasing maturity stage, total TRDP was reduced from 14.8 to 11.9 %DM, but total TRDC was increased from 23.3 to 30.7 %DM.

Effect of maturity stage on true protein supply to dairy cows and feed milk value of intercropping whole- plant oat (*Avena sativa* cv. CDC Haymaker) with whole plant faba bean (*Vicia faba* cv. CDC Snowbird) as hay in ruminant livestock systems, evaluated with the DVE/OEB system

Carlene Nagy, Victor Guevara-Oquendo, David A. Christensen, H. (Bart) Lardner, 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: peiqiang.yu@usask.ca

The objectives of this study were to determine effect of maturity stage at harvesting on true protein supply to dairy cows and feed milk value of intercropping whole plant oat (*Avena sativa* L. cv. CDC Haymaker) with whole plant faba bean (*Vicia faba* cv. CDC Snowbird) as hay in ruminant livestock systems, evaluated with the DVE/OEB system. The oat and faba bean plant were intercropped and grown in three fields with a seeding ratio of 0.5 bushel of oat grain to 4 bushels of faba bean seeds per acre (or 18 kg of oat seed to 269 kg of faba bean seed per hectare). The intercropped forages were harvested at three growth stages: maturity stage 1 was harvested when the oat plants were in the inflorescence stage and the faba bean plants were in the flat pod stage; maturity stage 2 was harvested when the oat plants were in the milk development stage and the faba bean plants were in the milk pod stage; and maturity stage 3 was harvested when the oat plants were at the soft dough stage and the faba bean plants were in the late pod stage. The results showed that the maturity stage did not significantly affect truly absorbed rumen synthesised microbial protein in small intestine (with an average of 48 g/kg DM), truly absorbed rumen undegraded feed protein in small intestine (with an average of 23 g/kg DM), and endogenous protein loss in small intestine (with an average of 26 g/kg DM). However, the maturity stage significantly affected ($P<0.05$) total truly digested protein in the small intestine (DVE) and degraded protein balance (OEB) as well as Feed Milk Value (FMV). The maturity stage 1 had higher ($P<0.05$) DVE value and OEB value than the maturity stages 2 and 3. The maturity stage 1 also had higher ($P<0.05$) FMV value than the maturity stages 2 and 3.

***Mycobacterium avium* subsp. *paratuberculosis* shedding and seropositivity in young stock on MAP-infected Alberta dairy farms**

A. Caroline Pereira¹, Karin Orsel¹, Jeroen De Buck¹, Larissa Martins¹, Marit M. Biesheuvel¹, Herman W. Barkema¹

¹Department of Production Animal Health, Faculty of Veterinary Medicine, University of Calgary. Email: anacaroline.pereira@ucalgary.ca

Johne's disease (JD), caused by *Mycobacterium avium* subsp. *paratuberculosis* (MAP), poses significant challenges to livestock industries, impacting economic stability, animal welfare, and potential human health. Control and eradication programs aim to mitigate these issues by reducing MAP prevalence. However, the prolonged prepatent period of JD, coupled with the limited sensitivity of diagnostic tests, complicates early detection and effective control. The primary objective of the study was to ascertain the age at which calves initiate shedding MAP in field conditions. Through repeated sampling over a 14-month period on eight Alberta dairy farms, the study aimed to provide insights into the onset of MAP testing in young stock (<12 months). Both serum ELISA and fecal qPCR (ISMAP02 gene) were employed as diagnostic tools. Results revealed that 12% of the sampled young stock tested positive for MAP by qPCR, while 4% showed positive ELISA results. Notably, ELISA-positive cases did not correlate with fecal qPCR positivity. Among the herds studied, those with higher within-herd MAP prevalence exhibited more positive qPCR results in young stock. Positive ELISA findings in animals at such a young age raised questions about maternal antibodies, with some calves testing positive despite having negative dams. The study also identified a herd where 24% of qPCR-positive young stock were offspring of positive dams. The shedding of MAP in young stock was observed as early as 4 months with qPCR, indicating the importance of early identification for timely removal and reduced transmission risk. Overall, the findings contribute valuable insights to enhance JD control and eradication strategies, emphasizing the significance of targeted sampling in young stock.

Take home message: The early identification of positive young stock is crucial to early removal and reduction of transmission. Additionally, targeted sampling in young stock is important to bolster the efficacy of JD control and eradication strategies, and disease management.

Effects of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079 probiotic supplementation during the late dry and early postpartum periods on feed intake and production responses of dairy cows

A. Pineda¹, S. Jantzi¹, K. Dekraker¹, S. Cartwright¹, M. Boerefyn¹, C. Villot², and M. A. Steele¹

¹ University of Guelph; ² Lallemand, SAS, France. Email: apinedab@uoguelph.ca

The study aimed to assess the effects of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079 supplementation (SCB; 1.0×10^{10} cfu/d) from d -28 to 70 relative to calving on dairy cow feed intake and production responses. Eighty-three multiparous (n = 52; MP) and primiparous (n = 31; PP) Holstein cows were blocked by previous 305-d milk yield, parity, body condition score (BCS), and body weight (BW), and randomly assigned to either prepartum and postpartum control (CON; n = 43) or SCB (n = 40) dietary treatments. The BCS and BW prepartum were measured weekly. Individual dry matter intake (DMI), milk yield, and postpartum BW were recorded daily. Milk samples were collected weekly and analyzed for fat, protein, lactose, urea N, and somatic cell count. Pre- and postpartum DMI and milk yield were similar among dietary treatments. However, 3.5% fat-corrected milk (FCM) was greater in SCB than CON cows (43.3 vs. 40.7 kg/d; $P = 0.05$) and in MP than PP cows (49.3 vs. 34.6 kg/d; $P < 0.01$). Milk fat content was greater in SCB than CON (4.44 vs. 4.24%; $P = 0.05$) and in MP than PP cows (4.39 vs. 4.29%; $P < 0.01$). Similarly, milk fat yield was greater in SCB than CON (1.65 vs. 1.53 kg/d; $P = 0.05$) and in MP than PP cows (1.90 vs. 1.29 kg/d; $P < 0.01$). Content and yield of milk protein and lactose were similar among dietary treatments. The MP cows had greater yields of milk protein (1.35 vs. 0.98 kg/d; $P < 0.01$) and lactose (2.01 vs. 1.45 kg/d; $P < 0.01$) than PP. Prepartum BCS was greater in CON than SCB cows (3.40 vs. 3.33; $P = 0.01$), but no difference was observed postpartum. Prepartum BW was similar among dietary treatments but greater in CON than SCB cows postpartum (673 vs. 653 kg; $P = 0.05$). In summary, supplementation of SCB during the dry period and early lactation in dairy cows increased FCM and milk fat content and yield and did not impact DMI.

Take home message: Supplementation of the live yeast *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079 during the late dry period and early postpartum period improved production responses in dairy cows.

Effects of calf starter, weaning, and butyrate supplementation on hindgut development in Holstein calves

S. G. Sayles¹, A. E. Mark¹, R. L. Hiltz², D. E. McCurdy², S. Moreland³, K. Klanderman³, A. H. Laarman^{1,2}

¹University of Alberta, Edmonton, Alberta, Canada T6G2P5; ²University of Idaho, Moscow, ID, USA 83844-2330; ³Adisseo USA Inc., Alpharetta, GA, USA 30022. Email: sayles@ualberta.ca.

The objectives of this study were to determine the effects of calf starter intake, the weaning transition, and butyrate supplementation on hindgut health of dairy calves. Thirty-six Holstein bull calves (age = 10.7 ± 4.1 d) were fed up to 1,200g/d of milk replacer and assigned to one of four treatments: 1) Pre-weaning groups fed only milk replacer (**PRE-M**), or 2) Pre-weaning group fed milk replacer, hay, and calf starter (**PRE-S**); 3) Post-weaning groups fed milk replacer, hay, and calf starter (**POST-S**); or 4) Post-weaning group fed milk replacer, hay, and calf starter supplemented with 1% wt/wt butyrate (**POST-B**). Both PRE-M and PRE-S were harvested at 48 days of age. Both POST-S and POST-B groups were weaned over 14 days, with milk replacer provision being reduced to 75% on day 49, 50% on day 56, and 0% on day 63. Both POST-S and POST-B groups were harvested at 10 weeks of age. Blood samples were collected on weeks 3, 5, and 7. At harvest, tissue samples of cecum, proximal colon, and distal colon tissue were collected and analyzed for genes involved in hindgut development, gut permeability, and immune responses; analysis of stress marker protein HSP70 was also conducted. Immune markers IL17A, TLR4, and TLR10 were upregulated in PRE-M calves, independent of tissue type. Additionally, these markers were upregulated in the cecum, regardless of dietary treatments. Hindgut development markers MKI67 and PCNA gene expression, as well as HSP70 protein content were higher in proximal colon than any other gut region. Gut permeability markers CLDN1 was highest in proximal colon, while OCLN was highest in the cecum. Serum amyloid-A concentrations decreased from week 3 to week 5.

Take home message: These data suggest that the cecum appears to be more immunologically active than the rest of the hindgut. Additionally, calf starter intake decreases inflammatory responses in the hindgut preweaning, and immune responses and epithelial development are dependent on hindgut region.

Linking farm management to dairy farmer mental and physical well-being

H. Tambadou¹, B. Zwick¹, A. Le Heiget¹, B. Hagen², A. Jones², J. Kinley¹, J.C. Plaizier¹, K. Ominski¹, C. Winder², E. Pajor³, and M. King¹.

¹University of Manitoba, ²University of Guelph, ³University of Calgary. Meagan.King@umanitoba.ca

Our objective was to understand how farm environment, housing type, milking system, and other farm-level factors are associated with farmers' mental and physical well-being. Dairy farmers (n=86) in Western Canada and Ontario completed an online survey that included questions on management practices, work and social environments, finances, cow welfare, and validated psychometric scales to assess stress, anxiety, depression, and resilience. Of the 86 farmers surveyed, 87% reported moderate stress and 13% reported high stress levels, and 31% and 22% of farmers reported mild and severe anxiety, respectively. There were 39% and 20% of farmers with scores indicating mild or severe depression, respectively. Analyses using t-tests and univariate linear models found that mental health scores did not differ based on gender, milking system, housing type, personal finances, time spent working alone, or animal welfare concerns. It was found that farmers who were most concerned about farm finance, feed costs, milk prices, workloads, and how much consumers valued them had higher levels of anxiety and stress ($P<0.05$). The highest depression scores were associated with concerns about farm finances, feed costs, and workload ($P<0.05$). Farmers who demonstrated greater resilience were less stressed by their workload. As for physical well-being, 84% of farmers experienced injuries and health problems while working on the farm. There were no differences in physical well-being based on milking system, housing type, or time spent working alone. However, the number of work-related injuries and health problems among men was greater than among women.

Take home message: Dairy farmers appear to have similar well-being in different production systems, but financial constraints, including high interest rates, inflation, and loan restrictions are key stressors. Financial support or other support resources may be needed for farmers to better understand and manage work stressors, to reduce stigma associated with mental well-being, and to instill compassion in consumers.

Understanding the connection between dairy farmer mental health and well-being and cattle health in Western Canada and Ontario

B. Zwick¹, H. Tambadou¹, A. Le Heiget¹, B. Hagen², A. Jones², C. Winder², E. Pajor³, J. Kinley¹, J.C. Plaizier¹, K. Ominski¹, and M. King¹
¹University of Manitoba; ²University of Guelph; ³University of Calgary; meagan.king@umanitoba.ca

The goal of this study is to explore the connection between dairy farmers' well-being and cattle welfare in tie stall, and loose housing (free stall, and bedded pack barns). Primary and/or secondary decision makers across Western Canada and Ontario completed online surveys (n=88) with validated psychometric scales to assess stress, anxiety, depression, and resilience. Surveys also included questions on farm management, calf mortality, and mastitis. Farms were also visited (n=66) to assess the health of lactating cows using measures similar to proAction for lameness, body condition, and knee, neck, and hock lesions. A representative sample of each herd (30% to a maximum of 69 cows) was assessed. Clinical and severe lameness were defined as cows with a locomotion score of ³3 or ³4 out of 5 respectively in loose housing, or ³2 or ³3 behavioural indicators respectively in tie stalls. Overall prevalence of clinical lameness was 7.9%, severe lameness was 2.3%, self-reported mastitis prevalence was 16.8%. In a linear model, higher anxiety scores were associated ($P=0.02$) with fewer over-conditioned cows ($BCS \geq 3.5$). Using t-tests, farmers with reported mastitis rates <10% had lower stress scores ($P=0.02$) compared to those with ³10%. Farmers with a clinical cow lameness prevalence of $\geq 5\%$ tended to have lower stress ($P=0.07$) and anxiety scores ($=0.06$), but higher resilience scores ($P=0.10$) than farmers with <5% lame cows. Using chi-square tests with a Bonferroni correction, more farmers who scored high on the stress scale had a clinical lameness <5% as compared to those scoring low ($P=0.009$) and moderate ($P=0.008$).

Take home message: Associations between farmer well-being and animal health were different than what was expected; farmers with better well-being scores were those with greater lameness and higher BC prevalence. However, greater mastitis prevalence was associated with higher stress.

Effects of omega-3 fatty acids supplementation on reproduction of dairy cows

G. Madureira¹, C. Van Dorp¹, I. Witelus¹, B. Van Winters¹, M. Santos¹, I. Avalos-Rosario¹, J. Bishop², T. Hansen², S. LeBlanc¹, D. Ma¹, E. Ribeiro¹
¹University of Guelph, Canada; ²Colorado State University, USA. Email: madureig@uoguelph.ca

Our objective was to evaluate the effects of omega-3 (**n3**) fatty acids (**FA**) supplementation on ovarian and uterine functions. Cows (n=104) were assigned into 1 of 4 dietary treatments from 2 to 90 DIM: 1) Unsupplemented Control; 2) CaPO: Calcium salts of palm oil; 3) CaFO35: Calcium salts of fish oil through 35 DIM; 4) CaFO90: Calcium salts of fish oil through 90 DIM. Fat was supplemented at 1% of DM. Blood and milk samples were collected at 14, 35, and 71 DIM for analysis of FA. Estrous synchronization was performed for timed AI at 70 DIM. Ultrasonography examination of ovaries and quantification of plasma progesterone were performed on d 0, 7, and 15 after AI. On d 15 after AI, uterine flushing (**UF**) and biopsy (**UB**) were performed for analysis of FA (UF and UB) and concentration of interferon-tau (**IFN- τ** ; UF only). The dominant follicle was aspirated 3 d after PGF_{2 α} injection for analysis of FA in the follicular fluid (**FF**). Supplementing CaFO increased concentrations of EPA+DHA in plasma (38.5 vs 14.4 μ g/mL) and milk (122.9 vs 46.9 μ g/mL) at 14 and 35 DIM, which remained higher in the CaFO90 group at 71 DIM. CaFO reduced the n6:n3 ratio in plasma (4.0 vs 5.2) at 14 and 35 DIM, which remained lower in the CaFO90 group at 71 DIM. There were no differences in size of the dominant follicle and luteal volume. However, CaPO and CaFO35 had higher plasma progesterone than CaFO90. Cows in the CaFO90 group had greater concentrations of EPA+DHA in FF (29.8 vs 10.9 μ g/mL) and UB (98.8 vs 56.7 μ g/g), and had greater concentrations of EPA in the UF (0.2 vs 0.08 μ g/mL). Based on IFN- τ concentrations in the UF, CaFO35 group had higher pregnancy per AI (68.8%) than the other groups (~33.0%). In pregnant cows, CaFO35 had higher IFN- τ concentrations than CaFO90 and Control.

Take home message: Supplementation of n3 FA in the early postpartum period benefited subsequent ovarian and uterine functions but these benefits were lost when supplementation was extended until the breeding period.

Effects of protected and unprotected butyrate supplementation on growth performance and fermentation profile in dairy calves

D.R. Martinez Mayorga*, K.R. Johnston, A.H. Laarman.
 University of Alberta, *Email: drmartin@ualberta.ca

Butyrate is known to promote growth performance in calves. Uncertainty persists on whether butyrate is more effective when unprotected, targeting the rumen, or protected, targeting the small intestine. The objective of this study was to evaluate rumen protected and unprotected butyrate supplementation on calf performance, as well as rumen and small intestine pH and short-chain fatty acid concentrations. Calves (n=21) were fed MR at 900 g/d and fed calf starter and water *ad libitum*. Animals were blocked by body weight, breed, and sex, and then assigned to one of three starter treatments: 1) No butyrate, 1% w/w palm fat as a placebo carrier (**CON**); 2) 1% w/w protected butyrate (2.5% of product; **PRO**); or 3) 1% w/w unprotected butyrate (1.5% of product) + 1% w/w palm fat (**UNP**). Calves were weaned with a two-stage stepdown from d 49 to 63 of age and were slaughtered at 70 d of age. Feed intake was measured daily. Blood and weight were sampled weekly. Feces and rumen fluid were sampled at 28, 42, 56 and 70 d of age. Digesta were collected at slaughter. At day 42, UNP calves had lower rumen pH than CON and PRO. Ruminal propionate and butyrate concentrations were higher in UNP than PRO, and higher in PRO than in CON. At d 56, ruminal propionate concentrations were higher in PRO and UNP than CON. At day 70, ruminal pH in PRO was higher than both CON and UNP, while duodenal pH tended to be higher in CON compared to PRO. UNP had a higher propionate concentration than CON. PRO tended to have a higher concentration of propionate than CON. At day 70, body weight was higher for CON and PRO compared to UNP. Both CON and PRO had greater starter intake than UNP. In duodenal digesta, propionate concentrations tended to be lower in UNP than CON.

Take home message: Fermentation profile is similarly altered by both supplements, but unprotected butyrate appears to compromise growth performance during weaning. Using a protected butyrate product may increase calf starter intake and growth which may decrease the time calves consume calf starter.