WORLD
ANIMAL
PROTECTION

Reducing antibiotic use

in farming through improvements to animal welfare

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Introduction and overview

The therapeutic use of antibiotics to treat and cure bacterial diseases is a vital component of protecting the health and welfare of animals used in food production. When an animal is ill, the prompt diagnosis and treatment of disease by a licensed veterinarian is a necessary step in restoring animal health and preventing the spread of disease to other animals on the farm.

However, for decades there has been a growing reliance by producers worldwide on administering antibiotics and antimicrobials to animals before they are sick to *prevent and control* the spread of disease rather than to *treat and cure* a sick animal or a disease outbreak. Therapeutic dosing of antimicrobials without the confirmed presence of disease is termed prophylaxis. Prophylactic antimicrobial use (AMU) allows farms – especially large-scale, industrialized agriculture systems commonly referred to as "intensive livestock operations" (ILOs) – to increase animal density, drive efficiencies and reduce costs without increasing animal morbidity and mortality that may otherwise occur from raising animals in sub-optimal environments. When it was discovered that some antibiotics had the added benefit of improving feed efficiency and promoting growth/weight gain, their use escalated.[1,2]

The overuse of antimicrobials over time can contribute to the spread of antibiotic resistant bacteria – sometimes called "superbugs" – as they move from farms into the surrounding environment and onto meat found on grocery store shelves, thus endangering public health.[3]

The unnatural, crowded conditions and other stress factors on farms can compromise animals' immune systems. Producers thus use antibiotics not to treat but to *prevent* potential infections as animals become more susceptible to disease. The overuse of antimicrobials over time can contribute to the spread of antibiotic resistant bacteria – sometimes called "superbugs" – as they move from farms into the surrounding environment and onto meat found on grocery store shelves, thus endangering public health.[3]

Resistant bacteria weaken the efficacy of the very drugs used to eradicate them and treat illnesses, resulting in prolonged illness and death for both animals and humans.[1,4(pp 1-2, 9, 12)] This is particularly concerning in the case of critically important antimicrobials for use in serious human illnesses. Health Canada has categorized the importance of these drugs as follows[5]:

Table 1. Health Canada categories for antimicrobials

Category	Description
I – Very High Importance	These antimicrobials are essential for the treatment of serious human illnesses. Very few or no alternatives are available if these don't work.
II – High Importance	These antimicrobials treat a variety of serious infections. Alternatives are generally available if needed, including Category I antimicrobials.
III – Medium Importance	These antimicrobials treat a variety of less serious infections. Alternatives are generally available, including Category I and II antimicrobials.
IV – Low Importance	Antimicrobials in this category are currently not used in human medicine.

Table 1 reproduced with permission from The Farmed Animal Antimicrobial Stewardship Initiative (FAAST)[5]

Details on which drugs are included in which categories can be found on the FAAST website amstewardship.ca.[5]

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Global concerns

Globally, the World Health Organization (WHO) has stated that antimicrobial resistance (AMR) is one of the top ten global public health threats and has estimated close to five million human deaths associated with bacterial AMR in 2019,[6] with 1.5 million deaths due to AMR lower respiratory infections.

Resistance to antibiotics which are often used as first line therapy for severe infections accounted for more than 70% of human deaths attributable to AMR pathogens.[4(pp1-2, 9, 12)] A 2014 review published by the UK Governments has estimated that antibiotic resistance could be the cause of over 10 million deaths by 2050[7(p5)] although the quantifiable accuracy of these estimates has been called into question.[8,9] Even so, the scientific community agrees the human death toll from AMR is apparent and predicted to grow.

10M Governments have estimated that antibiotic resistance could be the cause of over 10 million deaths by 2050.[7(p5)]

Canadian context

In 2015, the federal government announced it would be proposing measures to strengthen regulations on farm animal antibiotic use.[10] Three years later (in 2018), Health Canada implemented regulations requiring a veterinary prescription to purchase medically important antimicrobials and medicated feeds that were formerly available over-the-counter, and that all growth promotion claims be removed from product labels.[11] The aim was to ensure stricter control on antibiotic use. Further details on Canada's other policies and programs are outlined later in this report.

However, it is difficult to know if these measures have been effective since preventative AMU continues to be commonplace. Antimicrobials used to promote growth can still be prescribed to farm animals for preventative reasons in Canada as indicated in the 2020 report by the Canadian Antimicrobial Resistance Surveillance System (CARSS).[12]

Key findings from the CARSS 2020 report[12(pp79-85)] found that, in terms of mg/PCU (Population Correction Unit), in 2018, Canada distributed the sixth highest quantity of antimicrobials intended for use in animals (using European standard animal weights) compared to data from 31 European countries.

The CARSS 2020 report also stated that Canada sold 48 times more antimicrobials than Norway (the country with the lowest sales) and three times less than Cyprus (the country with the highest sales). Of the total active antimicrobials consumed in Canada in 2018, 79% was used on animals and 21% on humans.[12 (p88)] It is interesting to note that a 1995 decision by Nordic countries prohibits veterinarians from profiting from antibiotic sales.[13(p7489)] Denmark has been particularly successful with its profit ban and 2010 implementation of their "yellow card" system, with sector-specific antimicrobial use targets and where producers face penalties and fines for non-compliance.[14(p466),15]

In the CARSS follow-up 2021 report, the 2018-19 data showed an 11% decrease in use in animals overall, although there was an increase in its use in cattle, horses, companion animals and small ruminants.[16]

48x **Canada sold 48 times more antimicrobials than Norway (the country with the lowest sales)**[12]

A 2019 report by the BC Ministry of Agriculture on over-the-counter antibiotic sales by retailers such as feed mills and farm supply stores (excluding sales by veterinarians and pharmacists) suggests stockpiling of antibiotics occurred in 2018, before the new regulations took effect December 1, 2018.[17] Although tracking data from other provinces could not be located, if this also occurred outside of BC, it might explain Canada's 6th place ranking in 2018 for high quantities of antimicrobial distribution to livestock.

In 2018, Canada distributed the sixth highest quantity of antimicrobials intended for use in animals (using European standard animal weights) compared to data from 31 European countries.

A 2022 Health Canada report indicated a 7% increase in Canadian antimicrobial sales for use in food producing animals and horses in 2020 compared to 2019, with the largest increases in the use of the medically important drugs tetracyclines, streptogramins and penicillins. However, there was a decline in antimicrobial use from 2018 to 2019, so this could account for some of the increase the following year. Sales in 2020 of Category 1 drugs intended for use in dairy cattle increased by ~62% from 2019 to 2020 (the highest of any species).[18]

Another Health Canada 2022 report also indicated increased use of antimicrobials for pigs, chickens and turkeys in 2019 over the previous year, and that a small percentage of antimicrobials are still being used for growth promotion in grower-finisher pigs. It stated the bulk of antimicrobial use for pigs, chickens and turkeys was for enteric disease prevention rather than treatment.[19(p75)] The data in this report was collected voluntarily from 352 sentinel farms participating in the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS).

The multiple reports and statistics circulating in the public domain make it difficult to get a consistent and accurate picture of the true state of AMU on Canadian farms. "We do not have any structured way to collect data or any real idea how antimicrobials are used on farms. Sales data are a start, but they are a crude indicator" (Dr. S. Weese, DVM, DVSc, Dipl ACVIM, email communication April 15, 2023). Nonetheless, the available data makes it clear that AMU is high in animal agriculture, making it a contributor to AMR and indicating there is room for reduced use in this sector.

Global efforts to mitigate AMU

There has been a global effort to ban the use of antibiotics for growth promotion and prophylactic disease prevention purposes in farm animals. The first ban was implemented in Denmark in 2000[20] which was followed by the EU-wide ban in January 2006 making it illegal to administer antibiotics across groups of farm animals via feed to promote growth.[21,22] The ban was extended in January of 2022 to include the prophylactic use of antibiotics and antimicrobials to control and prevent the spread of infection, and applies to animals and animal products imported into the EU.[23-26]

Denmark also requires veterinary prescriptions for all antibiotic use in food animals. Their poultry and swine producers voluntarily halted the use of growth promoting antibiotics before the national ban took effect in 2006. This resulted in a 35% drop in the total use of livestock antimicrobials between 1996-2003, although they also reported a doubling of annual therapeutic use, mainly from administration to weaning pigs.[20(p6)]

The following is a timeline of Denmark's restrictions on AMU:

- **2002** – Prohibited veterinary use of fluoroquinolones (a Category 1 antibiotic) except when it is the only effective option and, even then, government officials must be notified
- **2005** – Initiated bi-annual audits of swine veterinarians, and eventually all livestock veterinarians
- **2010** – Voluntary ban by the Danish swine industry on the use of third-generation cephalosporins
- **2010** – Implemented "yellow card initiative" setting regulatory limits on antibiotic use based on the size of a swine farm (thus shifting the burden for minimizing antibiotic use from veterinarians to farmers). This reportedly led to a 25% drop in antibiotic use in livestock production.[14,20(p6)]

Denmark reduced its antibiotic use by 60% between the mid-90s and 2012[14(p1)] and by 56% between 2007-2012 alone.[27] What is even more remarkable is that Denmark was able to implement these regulations and processes - even though they are one of the world's largest exporters of pork – with no negative effects on productivity.[14(p1)] Denmark's pork industry officials hope to raise 1.5 million pigs completely free of antibiotics by 2024, up from 200,000 in 2018. While this was a relatively small percentage of the 32 million pigs it reportedly produced in 2018, it was and continues to be a step in the right direction.[28]

As of January 2022, the European Union banned the prophylactic use of antibiotics and antimicrobials to control and prevent the spread of infection, and this applies to animals and animal products imported into the EU.[23-26]

With such significant gaps amongst countries in priorities, policies, regulations and timeframes, and considering lessons learned from the Covid-19 pandemic, there has been renewed interest in the role zoonotic diseases could play in the next pandemic. On March 2, 2022, the European Council announced plans to authorize the opening of negotiations for an international agreement or instrument governing pandemic prevention, preparedness and response. The working draft is an evolving document and the aim is to adopt the instrument by May 2024.[29]

The WHO published a 'Zero draft' in February 2023 which recognizes AMR as a silent pandemic that could be an aggravating factor during a pandemic. It urges countries to address AMR in their pandemic prevention preparedness plans and national One Health action plans.[30] A One Health approach has been defined as "an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent".[31]

The threat of AMR is important to retain in the Pandemic Instrument[30] given AMR is expected to result in significant excess hospital costs and millions of human deaths by 2050.[32] Simulations by the World Bank estimate that by 2050, AMR-related global health expenditures could range between $0.33-$1.2 trillion annually.[33]

Photo: Cattle eat from a long trough at a feedlot in Québec, Canada. 2022
Credit: Jo-Anne McArthur / We Animals Media

Ionophores – the "low importance" antimicrobials

One way animal agriculture adheres to the regulations restricting AMU, particularly for growth promotion and feed efficiency, is by using ionophores. Although they are not considered an antibiotic in Europe, in Canada they are classified as a Category IV antibiotic – Low Importance. They are not used in humans due to toxicity concerns[34] thus their use in animal agriculture is not restricted. It should be noted they can also be toxic to cattle (heart failure) and other animals when dosage errors occur.[35-37]

Derived from naturally occurring bacteria like other antibiotics, ionophores work by inhibiting the functionality of bacteria and by increasing the permeability of the gut wall in animals and poultry to increase nutrient absorption and thus deliver production and feed efficiencies, and, in cattle, reduce their methane emissions.[34] They are the second most widely used class of antibiotics in animal agriculture in both the US[12(p97),38(pp29-30)] and Canada[39(p97)] and it is estimated that 90% of cattle on feed in North America are fed ionophores.[34(pp1-2),40] Interestingly, while both the 2016 US Summary Report of Antimicrobials Sold or Distributed for Use in Food Producing Animals and the 2016 CARSS report included data on ionophore use, the US 2019 and CARSS 2020 reports purposefully excluded it.

Medically, ionophores are used to treat and/or prevent several animal diseases: coccidiosis and necrotic enteritis in poultry and other species, liver abscesses, bloat and acidosis in feedlot beef cattle, and ketosis in dairy cattle (Dr. T Duffield, DVM, DVSc, email communication, February 17, 2022). However, for beef cattle and pigs, their primary benefit appears to be feed efficiency and weight gain.[41,42] In fact, their economic advantage can be significant, bringing a return on investment in beef of $6 for every $1 spent, and an increase of $20 per cow.[40]

Some scientists suggest more study is needed to determine if ionophores impact cross-resistance to certain antibiotics such as vancomycin and erythromycin.[34,43] However, other scientists, producers and veterinarians feel they are safe, and the production efficiencies gained from their use outweigh the risks.[44,45] Given systems have been established to monitor the agricultural use of antibiotics needed for human medicine, it would be prudent to track ionophore usage in livestock (and on-farm use of other antimicrobials) in the event cross-resistance or other negative impacts on animals, human health and the environment develop in the future.

Timeline of Canada's national AMU policies and programs

Since the launch of the Canadian Institutes of Health Research (CIHR) in 2000, several programs have been initiated to address AMR using the One Health framework. Canada has undertaken a multi-stakeholder approach across federal, provincial and territorial governments along with stakeholders from public health, animal health, agri-food sectors, academia and industry.[46]

In 2014 the Public Health Agency of Canada (PHAC) initiated the Canadian Antimicrobial Resistance Surveillance System (CARSS) and the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) – the latter combining data from human, animal and food sources.[46]

In October of 2014, the Government of Canada released: "Antibiotic Resistance and Use in Canada: A Federal Framework for Action" which mapped out a collaborative federal approach to responding to the threat of AMR.[47] In 2015, the federal government's follow up report highlighted three pillars – Surveillance, Stewardship and Innovation – and identified concrete actions to reduce the threat and impact of AMR.[47,48] Then, in 2017, the Pan Canadian Framework for Action was launched, adding Infection Prevention and Control as a fourth pillar[49] and recommending the development of a Pan Canadian Action Plan.[50] In 2018, regulations were enacted requiring a veterinary prescription for use of all medically important antimicrobials in animals (thus prohibiting over-the-counter sales) and banning growth promotion claims on the labels.[11] While the over-the-counter sales regulation mirrors the Denmark policy and is a step in the right direction, its effectiveness in Canada is not known since data collection at the farm level regarding who makes the treatment decisions and the reasons for antibiotic use is limited.

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In 2019 PHAC also established the AMR Network – a stakeholder coalition fostering collaboration and knowledge-sharing among existing AMR groups. Its goals were to turn action plans into actions and propose AMU governance models to strengthen Canada's AMR response for human health.[51]

The AMR Network submitted a proposal to PHAC in June 2021 titled "Strengthening Governance of the Antimicrobial Resistance Response Across One Health in Canada" in which it outlined two models:

1. **"The AMR Network"** – this model uses a decentralized approach with an open culture whereby a network of experts continues to collaborate and there is no single point of control; and
2. **"The AMR Centre"** – this model proposes a more structured, centralized, top-down approach with its own staff and infrastructure making decisions and would be positioned as the focal point for AMR activity in Canada.[52(pp5-6)]

On June 22, 2023, a decision was announced to proceed with the decentralized "network of networks" approach, and to add a 5th pillar – Leadership – to the Action Plan.[53] The AMR Network, with its task complete, appears to have been disbanded (the AMRNetwork.ca website no longer exists).

Animal-specific AMU tracking policies and programs

In 2016, the Canadian Animal Health Surveillance System (CAHSS) AMU Network – now an initiative of Animal Health Canada (formerly the National Farmed Animal Health and Welfare Council) was established as a multi-stakeholder group from Canada's animal production sectors to explore harmonizing data inputs and outputs.[54(p2)]

In terms of animal-specific AMU, Canada has two official data sources:

1. CIPARS (Farm AMU/AMR Surveillance program)
2. Veterinary Antimicrobial Sales Reporting (VASR) system

CIPARS is a voluntary initiative that collects farm use data from a network of sentinel veterinarians and producers in specific livestock sectors across Canada.[54(p2)] However, the number of sentinel farms is limited within their chicken, turkey, pig and feedlot programs, and surveillance is limited in some cases (e.g. pigs) to the final production phase.[55(p6)] A mandatory program requiring participation by all farms in all production stages – phased in over time – is a worthy consideration to improve AMU/AMR tracking, although it could be costly and time-consuming for producers.

The purpose of the VASR system – initiated in 2018 as a component under the CIPARS umbrella - is to collect data on the sale of veterinary antimicrobials considered important in human medicine, and to estimate sales by animal species.[54(p2)] However, the mandatory reporting of annual sales data only applies to manufacturers, importers and compounders of these drugs[56], unlike European programs that collect data from veterinarians, farmers and feed mill (medicated feed) sales. Without the farm level data, understanding how antimicrobials are being used limits policy makers in their ability to guide impactful and necessary actions to combat AMR.

Complementing these initiatives is the CVMA's Stewardship of Antimicrobials by Veterinarians (SAVI). Formed with funding from and in partnership with the federal government, SAVI's 4-year mandate (2019-2023) will support national stewardship and data collection elements to enhance veterinarian decision-making regarding AMU.[57] Since veterinary prescribing and dispensing data are not yet available under the CIPARS VASR system, SAVI will fill this gap through its veterinary practice AMU data collection system.[54(p12)]

At a provincial level, there are two key animal AMU initiatives. In Quebec, effective February 25, 2019, antibiotics of very high importance to human medicine (Category 1) can only be used in food animals for curative purposes (treating disease that is present) if no lower category option is effective, and are forbidden as a preventative measure in any food animals.[58] Quebec is also developing its own AMU surveillance and data collection program for food animals raised in the province,[54(p12)] although they have had a passive surveillance program in place since 1993.[58(p193)]

In Ontario, a collaboration between the Ontario Veterinary Medical Association, government, academia and industry launched the Farmed Animal Antimicrobial Stewardship Initiative (FAAST).[59] In addition to improving antimicrobial stewardship, FAAST will prepare for upcoming policy and regulatory changes and aims to preserve the efficacy of antimicrobials without compromising animal health or food safety through engagement, collaboration and education.[60]

While the previous policies, programs and organizations deal specifically with AMU/AMR in humans and animals, the root cause of why so many antimicrobials are given to animals in the first place – sub-optimal animal management practices – has not been addressed. Historically each livestock sector has been responsible for its own animal husbandry standards, however, the main guidelines for animal care on Canadian farms are now through the Codes of Practice, which are developed through multi-stakeholder committees overseen by the National Farm Animal Care Council (NFACC).[61]

Without the farm level data, understanding how antimicrobials are being used limits policy makers in their ability to guide impactful and necessary actions to combat AMR.

Although the Codes have resulted in some progressive changes to animal care and management, most are not enforceable by law, regulation or penalty. Most commodity groups (e.g. the Dairy Farmers of Canada) require their members to meet the Code requirements (but not the recommendations) and have programs of varying rigour to ensure they are met. More concerning, however, is the fact that AMU/AMR issues and measures have not been addressed in any of the Codes of Practice.

Canada's participation in international AMU policies and programs

Internationally, Canada is a member of several AMU organizations and programs including The Joint Programming Initiative on Antimicrobial Resistance and its Virtual Research Institute, the Global Antimicrobial Resistance Research and Development Hub and the Transatlantic Task Force on Antimicrobial Resistance.[50]

Canada also enrolled in the World Health Organization's Global Antimicrobial Resistance and Use Surveillance System (GLASS), launched in 2015. However, in response to the 2020 call for data, Canada did not report any AMR data to GLASS and does not appear to have provided any information since 2015.[62]

Canada is not represented on the WHO's Global Leaders Group on AMR, although Dr. Scott Weese, veterinary internal medicine specialist and the Chief of Infection Control at the University of Guelph's Ontario Veterinary College, is a member.[63] Among the Global Leaders Group's recommendations is a focus on infection prevention and control, with reference to decreasing density and increasing ventilation to improve animal health and welfare (Dr. S. Weese, DVM, DVSc, Dipl ACVIM, oral communication, January, 25, 2022). This focus on animal agriculture was reiterated in the AMR Network's 2021 proposal to PHAC in which it stated as one of its four strategic goals *"Reduce the need for antimicrobial treatment by promoting infection prevention and control practices to decrease infection rates in healthcare, community, and animal settings"*.[64]

Given the importance of animal health and welfare to preventing AMR, better animal management and housing practices will have far more impact on reducing AMR than designating individual drugs or groups of antibiotics to prohibit. Thus, understanding Canada's laws and regulations governing the protection of animals – and farm animals in particular – is key.

Unfortunately, Canada's animal protection laws and regulations vary across local, provincial, territorial and federal lines. They are a patchwork of voluntary and mandatory participation, inspection and enforcement and varying definitions of the same terms, all of which can create confusion, inconsistency, duplication, jurisdictional difficulties and may even erode public trust.[65] Although most of the laws do establish protection for animals from cruelty and distress, the laws pertaining to farm animals allow for exemptions regarding "reasonable and generally accepted management practices"[66] which means poor farm animal welfare practices are exempt simply because they are commonly used and normalized within the agriculture industry.

Despite all these surveillance and stewardship initiatives, when it comes to responsibly addressing AMR, Canada has been a disappointment, falling behind many G20 and even low and middle-income countries in terms of concrete objectives, mandatory tracking, evaluation and penalties.[67(p28),68]

Among the WHO's AMR Global Leaders Group's recommendations is a focus on infection prevention and control, with reference to decreasing density and increasing ventilation to improve animal health and welfare.

Unfortunately, Canada still permits routine prophylactic antibiotic use in farmed animals. So long as it can be prescribed to prevent the *possibility* of disease, this offers producers and veterinarians a loophole for continued use to promote growth.[69(p164)] It is important to note that some large group prophylaxis during specific disease events is necessary to prevent illness and death in many animals, but this does not preclude a ban on prophylactic use in most circumstances where "routine" or excessive use is the norm.

Furthermore, Canada has not yet taken steps to fully track the sales of prescriptions and use by veterinarians and pharmacies (Dr. B. Radke, DVM, PhD, email communication, Nov 7, 2022), nor track use at the farm level, or cap monetary profits on veterinarian sales the way some European programs do, as referenced earlier in this report.[13]

"While the federal government publicly released its Pan Canadian Framework for Action on AMR in 2017, there has been limited political commitment to fund and act on many of the recommendations. It was not until 2023 that the Pan Canadian Action Plan was launched, and it is still unclear how (or whether) it will be adequately funded and supported. Political will and engagement are needed to drive changes that will truly inform about how antimicrobials are used in Canada through mandatory reporting (collection/submission) of AMU (what drugs used, for what purpose and decision to use/administered by whom) in animals, and provisions to monitor, support and, at a last resort, penalize those who continue to use antimicrobials inappropriately" (Dr. S. Weese, DVM, DVSc, Dip ACVIM, oral communication, July 24, 2023). Moreover, addressing the root causes driving the need for AMU on Canada's farms in the first place is a necessary step to reducing antibiotic overuse and its impacts.

Table 2. Summary of Canada's Major AMU/AMR Policies, Programs and Regulations

Policy/Program/ Report/Regulation	Jurisdiction	Focus/Mandate	Year of Initiation or Project Scope
Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS)	Federal: PHAC	National surveillance program which collects, analyzes and communicates trends in AMU and AMR for select bacteria from humans, animals and retail meat across Canada in order to contain the emergence and spread of resistant bacteria between animals, food and people with the aim of prolonging the effectiveness of antimicrobials.	2002
Joint Programming Initiative on Antimicrobial Resistance (JPIAMR)	International: Canadian Institutes of Health Research (CIHR) is an active member and major funder of the Management Board of JPIAMR	A collaborative platform engaging 29 countries to curb AMR with a One Health Approach, it coordinates national public funding to support transnational research and activities within 6 priority areas: therapeutics, diagnostics, surveillance, transmission, environment and interventions.	JPIAMR launched in 2011, Canada joined in 2013
Canadian Antimicrobial Resistance Surveillance System (CARSS)	Federal: Public Health Agency of Canada (PHAC)	National system for reporting on AMR and AMU, synthesizing and integrating information from PHAC surveillance programs across the human and agricultural sectors, tracking consumption by antimicrobial class.	2014
Antibiotic Resistance and Use in Canada – A Federal Framework for Action	Federal: PHAC	Protect Canadians from the health risks related to AMR and map out a collaborative federal approach to responding to the threat and impact of AMR	2014
Federal Action Plan on Antimicrobial Resistance and Use in Canada: Building on the Federal Framework for Action	Federal: PHAC	Follow up to 2014 report in order to identify concrete actions to reduce the threat and impact of AMR, highlighting 3 pillars: Surveillance, Stewardship and Innovation.	2015
Global Antimicrobial Resistance and Use Surveillance System (GLASS)	International: World Health Organization (WHO)	To strengthen knowledge through surveillance and research and to provide a standardized approach to the collection, analysis, interpretation and sharing of data by countries, and to actively support capacity building and monitor the status of existing and new national surveillance systems.	2015, and Canada joined in 2015
Canadian Animal Health Surveillance System (CAHSS) AMU/AMR Network	Federal: Animal Health Canada	A forum for governments and industry stakeholders to share information and work collaboratively on safeguarding the effectiveness of antimicrobials.	2016
Pan Canadian Framework for Action	Federal: PHAC and co-chaired with Canadian Institutes of Health Research – Institute of Infection and Immunity (CIHR-III)	Follow up to 2014 and 2015 Framework for Action, recommending development of a Pan Canadian Action Plan, and adding a 4th pillar: Infection Prevention and Control	2017
Veterinary Antimicrobial Sales Reporting (VASR)	Federal: CAHSS	Tracking, reporting and estimation of sales of medically important antimicrobials by animal species	2018
Regulation – Responsible Use of Medically Important Antimicrobials in Animals	Federal: Health Canada	Regulation requires veterinary prescription for use of all medically important antimicrobial (thus prohibiting over-the-counter sales) and bans growth promotion claims on antimicrobial labels	2018

Policy/Program/ Report/Regulation	Jurisdiction	Focus/Mandate	Year of Initiation or Project Scope
JPIAMR Global AMR Research and Development Hub	International: Vice-Chaired by PHAC with input from CIHR	To maximize the impact of existing and new initiatives in antimicrobial basic and clinical research and product development by connecting funders around the world to facilitate information exchange on funding streams and promote high-level alignment of funding to mobilize additional resources.	2018
Stewardship of Antimicrobials by Veterinarians Initiative (SAVI)	Federal: Managed by Canadian Veterinary Medical Association (CVMA) with funding from the Government of Canada and the Canadian Agricultural Partnership.	Stewardship and data collection elements to enhance veterinary decision-making regarding AMU, including veterinary prescribing and dispensing data (filling gap currently not provided under CIPARS and VASR)	2019-2023
The AMR Network	Federal – Public Health Agency	Turn actions plans into actions and to propose a governance model for coordinating Canada's AMU/AMR actions	2019-2021
JPIAMR Virtual Research Institute (VRI)	International: Led by CIHR-III	A virtual platform to connect research networks, and research performing institutes, centres and infrastructures beyond sectorial and geographic boundaries. The JPIAMR-VRI provides knowledge exchange and facilitates the analysis of knowledge gaps, increases capacity, improves coordination, implements breakthrough collaborative research and increases the visibility of the research performed, thus facilitating alignment of strategies, and the production and sharing of scientific evidence.	2021
Farmed Animal Antimicrobial Stewardship Initiative (FAAST)	Provincial: Ontario	Collaboration between Ontario Veterinary Medical Association, academia, government and industry to provide farmed animal owners and their veterinarians with the news, tools and resources they need to help prevent antimicrobial resistance, to prepare farmed animal owners and their veterinarians for upcoming policy and regulatory changes, and to preserve the efficacy of antimicrobials without compromising animal health or food safety.	~2018
Québec Multispecies AMU Surveillance System	Provincial: Québec	AMU surveillance system based on sales data collected at the farm or veterinary clinic of AMU for food animals.	1993 (passive system launched) and implementation of new provincial-federal system planned for 2023-2025.
Pan Canadian Framework for Action	Federal: PHAC	Model for governance chosen – a decentralized, collaborative, network of networks approach – and addition to Action Plan of 5th pillar: Leadership	2023

Photo: Pigs waking up from nap in the straw at an animal sanctuary in Switzerland, 2022.
Credit: Sabina Diethelm / We Animals Media

Literature review resources

Hundreds of research studies, articles, videos, promotional materials and reports from numerous university, government, industry, non-profit and association sources were reviewed. Commonly searched scientific databases included Frontiers in Veterinary Science, ScienceDirect, PubMed, Vet World, Animals, and Journal of Dairy Science, among others. Reference lists within studies selected were also scanned for further relevant studies and articles. Stories and articles from reputable media outlets (e.g. TV, newspaper, magazines) were also reviewed.

Studies and articles published since 2010 were prioritized, with many published after 2015, and with preference to post-2018, to reflect more current policies, regulations, statistics, impacts and findings with respect to farming practices and AMR. Information was also gathered via phone and email communications with Canadian animal scientists and veterinarians. Most of the literature review and communications were conducted between December 2021-July 2022, with some occurring in 2020 and 2023.

Literature review – Summary of the findings

The excessive use of antibiotics in animal agriculture, mainly through routine prophylactic use, is a recognized problem and contributor to AMR. To better understand where and how AMU can be reduced or eliminated altogether, it is important to understand the practices and conditions under which antibiotics are most often used and for what purposes. This report provides a high-level review of recent scientific literature concerning the prophylactic use of antibiotics in the production of animal protein globally and in Canada. Linkages between AMU and animal husbandry and management practices in the dairy, beef, pork, and poultry industries are identified. The literature demonstrates that, with improvements in animal care practices on farms, AMU could be lessened or eliminated.

In summary, the research shows there are several common practices in animal agriculture that account for the reliance on prophylactic antibiotics, including:

1. Weaning methods (i.e., how abruptly offspring are weaned and separated from their mothers)
2. Housing environments (particularly crowded, barren, unsanitary environments and mixing of unfamiliar animals)
3. Breeding tactics favouring animals with hyperprolific reproductive capacity (e.g. sows with larger litter sizes) or selected for increased production (e.g. laying hens, dairy cows), or faster growing/larger animals (to satisfy demand for human consumption of animal protein)
4. Medication protocols to improve feed efficiency and body mass/weight gain

The purpose of the above practices is economic and production efficiency. However, these so-called efficiencies in turn create inefficiencies. Directly and indirectly, they can increase susceptibility to bacterial and viral infections because of undue stress that in turn can compromise the animals' immune systems. The crowded living conditions mean disease can spread quickly through the animal group. Having to treat sick animals results in increased medical costs in addition to production losses, animal morbidity and mortality. Producers turn to routine and often excessive prophylactic use of antimicrobials to prevent disease from happening in the first place. This drive for high productivity, cost reduction, efficiency and increased profits in animal agriculture has come at the expense of both farm animal welfare and human health.

Policy recommendations for regulatory changes, oversight, data collection and measures to support producers in making animal welfare improvements at the farm level are highlighted in the literature review and discussion.

Literature review and discussion

Protein production – Dairy cattle

Dairy industry overview

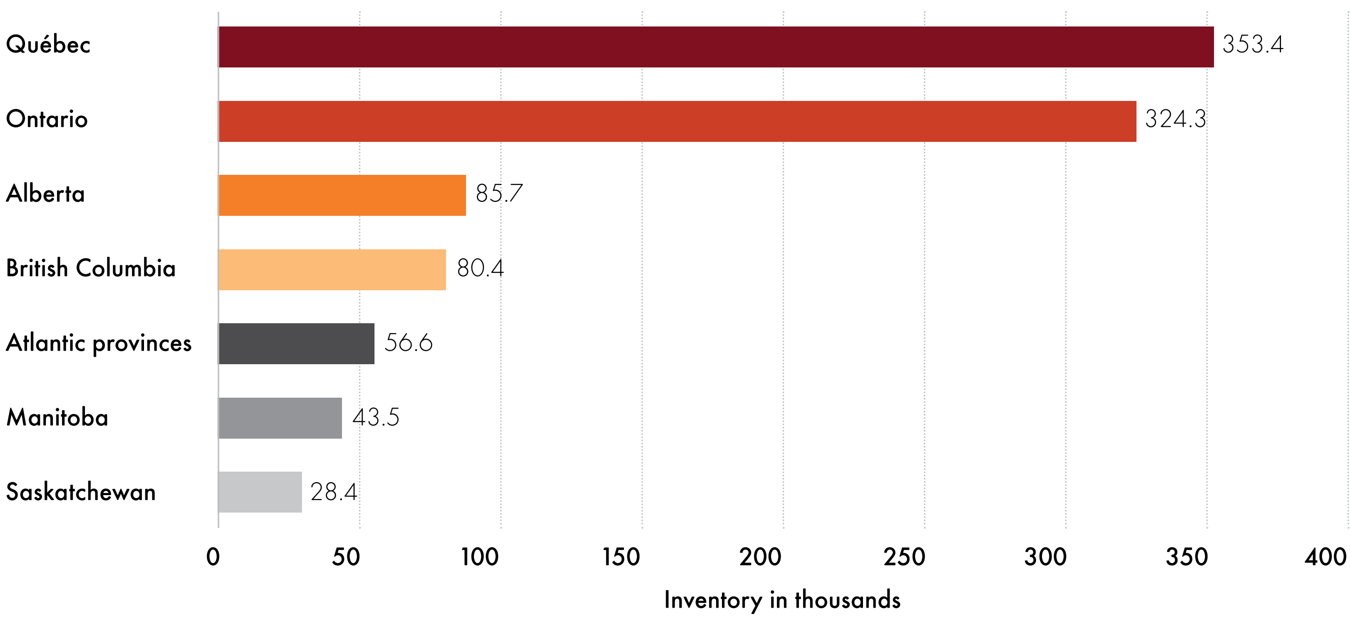
As of August 2022, there were 1.3919 million dairy cows and heifers (young female cows that have not yet borne a calf) on 9739 dairy farms in Canada with net farm cash receipts totaling $8.23 billion.[70] Canada's main export markets for our dairy products are the United States, Saudi Arabia, the Netherlands and France. [71] Of the 94.5 million hectoliters of milk produced, only 1.49 million hectoliters were organic milk.[70]

In 2022, most dairy farms were in Quebec (4548) and Ontario (3298) with the remainder of Canada's farms (1893) reporting less than 500 farms per province (and as little as 25).[72] Ontario and Quebec account for nearly 81% of Canada's dairy farms.

Excluding heifers there were approximately 353,400 dairy cows in Quebec, 324,300 in Ontario, 85,700 in Alberta, 80,400 in BC, 56,600 in the Atlantic provinces, 43,500 in Manitoba and 28,400 in Saskatchewan.[72]

The size of dairy farms varies greatly across the country, with herd sizes ranging from as small as 30 cows and as large as 1,000 or more. Due to the wide range, the average herd size was reported by Dairy Farmers of Canada in 2021 as 96 cows per farm with an average of 75 to 95 cows per barn in Quebec and Ontario, and western provinces housing an average of 130-175 animals per farm.[73]

Figure 1. **Dairy cow inventory in Canada as of 2022 by region** *(in thousands)*



Source: Statistics Canada, Dairy Farming in Canada, 2022. Ontario and Quebec account for nearly 81% of Canada's dairy farms.

Photo: Dairy cattle on a farm in Canada. Credit: Shutterstock

Mastitis in the dry-off period

Within the dairy industry, the main use of antibiotics is during the "drying off" period (typically lasting 60 days) – a cow's transition from the lactating to non-lactating state prior to the next calving period.[74-76] Good management practices in this period generate higher milk production in the subsequent lactation.[77(ppiii-iv)]

Antibiotics are used during dry-off to control mastitis, a painful inflammation of the mammary gland that often results in infection. Mastitis can occur when one or more teats do not close quickly enough or fully after milk cessation and bacteria enters the teat. It is the most common infectious disease affecting dairy cattle.[78(pp1, 4-8)] It is also the most costly disease for dairy producers as it leads to reduced milk production, inferior milk quality and an increase in discarded milk due to antibiotic residues from treated cows, not to mention premature culling of cows with severe clinical mastitis.[75(p22),79]

Mastitis prevention and treatment accounts for at least half of all antimicrobials used on dairy farms worldwide. The administration route is predominantly topical or intramammary infusion (which has lesser resistance concerns), but intramuscular and intravenous injection and oral routes are also used.[80] The most common antibiotics used are cloxacillin, penicillin-aminoglycosides, and cefapyrin products – considered Category I and II (Very High and High Importance) antibiotics.[75(p22),81(p11),82] In Canada, mastitis, reproductive conditions, and dry cow therapy were the most frequent reasons for antimicrobial therapy in studied herds. Penicillins, first generation cephalosporins, trimethoprim and sulfonamide combinations, and tetracyclines (Categories II and III) were the most commonly used antimicrobials.[83(pp9740, 9744)]

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Dry cow therapy

To prevent and control mastitis infections, dairy farmers implement one of two dry cow therapy (DCT) protocols: blanket DCT or selective DCT.

Blanket DCT implies that a prophylactic or blanket antibiotic approach is applied to all lactating cows in the herd, to all udder quarters (and all teats) regardless of infection status.[84] Selective DCT means cows are assessed individually to determine if the individual animal has an infection, or is at considerable risk for infection, and is treated with antibiotics accordingly.

Selective DCT assessment includes checking somatic cell counts (SCC) for bacterial growth in milk, and checking udders for pain, inflammation, redness or leakage.[85] Somatic cells include leukocytes (white blood cells) which, when present in the teat or udder at a high level (over 300,000), indicate the possible presence of an infection.[86] In Canada, herd level milk testing must show counts of less than 400,000 to be eligible for sale to consumers.[87]

The majority of dairy producers worldwide use blanket DCT to prevent mastitis.[13] In 2016, it was estimated that in Canada and the UK, blanket DCT was practiced on 88% and 99% of farms, respectively.[85(pp3753-3754)] In Germany, Bertulat's 2015 study of dairy farmers in Northern Germany found almost 80% of participating commercial dairy farms used blanket DCT and almost 65% of all antimicrobial DCT was conducted without an assessment of the milk for bacteriological need.[88]

There are very few studies indicating the adoption rates of selective DCT on Canadian dairy farms. Unfortunately, no recent published studies are available demonstrating what impact the new AMU regulations may have had on increasing selective DCT. Lactanet has been providing tools and education to farmers over the past two years to help them learn more about the practice,[89] thus it is possible there has been an increase in this approach. Two dairy veterinary experts interviewed for this report estimated 40-50% of Canadian farms may now be practicing some form of selective DCT.

Dry-off can be done gradually (over days or weeks) or abruptly (within one day). Abrupt dry-off is the most common method worldwide because it is easier to implement, especially in large herds that are calving year-round as opposed to seasonally. In the US and Germany, 2014 reports showed over 70% of farms practiced abrupt dry-off.[77,88(p1)]

In the Netherlands, prophylactic antibiotic use at dry-off was prohibited in 2013,[84(p8260)] and selective therapy combined with a gradual dry-off period is more common in some European countries.[85(p3762)] In Finland, 78% of dairy farms practice gradual and selective DCT[13(p1)] and the Netherlands tends to administer antibiotics selectively based on signs of mastitis. A 2016 study of 177 Dutch dairy farmers (with a median herd size of 90 lactating cows) found 75% of the farmers had a positive mindset around selective DCT and had begun practicing selective therapy after the 2013 prohibition even though they initially had no guidelines on how to implement it effectively (guidelines were provided by the Royal Dutch Veterinary Association in 2014).[84(p8260)] In Denmark, preventative measures to control intramammary infections are emphasized and antibiotic DCT is only recommended if contagious mastitis is present.[13(p7488)]

In the Netherlands, prophylactic antibiotic use at dry-off was prohibited in 2013,[84(p8260)] and selective therapy combined with a gradual dry-off period is more common in some European countries.[85(p3762)] In Finland, 78% of dairy farms practice gradual and selective DCT[13(p1)] and the Netherlands tends to administer antibiotics selectively based on signs of mastitis.

Given the concerns over AMR, there has been much research on more effective dry-off practices to hasten teat closure and reduce reliance on antibiotics to prevent and treat intramammary infections and mastitis. A study of US and Canadian herds demonstrated that the level of milk production before dry-off was the most important factor influencing the speed of teat closure.[90] High milk yield cows with an abrupt dry-off were more susceptible to mastitis due to slower closing teats, and teat closure was faster in lower-producing cows.[78(p6)] Among cows milking less than 21 kilograms per day, 70% of teat ends closed in the first week and mastitis was reduced. Only 43% of teats closed in cows with high milk production levels.[90] Cows with high milk yields may also be less resilient and more susceptible to clinical mastitis.[91(p6)]

To aid in milk reduction in the dry-off period, Vilar's 2020 review of the research literature found when cows' feed rations were unrestricted but nutrient or energy density was reduced, milk production was gradually reduced without inducing hunger. Furthermore, the combination of gradual dry-off with nutrient density reduction accelerates the formation of the teat canal's keratin plug (which naturally forms when milk production stops), thus preventing milk leakage, bacterial infection and mastitis.[78(pp6-7)] Thus gradual dry-off with reduced energy nutrients while maintaining feed volume appears to be the most effective method to protect against mastitis in the next lactation and keep cows comfortable.[90] Logically, it follows this practice would also reduce AMU.

Success in preventing leakage/mastitis has also been demonstrated with the use of teat sealants.[92,93] Sealants, which mimic the protective effects of the keratin plug, can be infused internally to the teat cistern, or applied to the teat exterior,[79(p6495)] providing an effective adjunct or alternative to the use of antibiotics. Sealants alone can significantly reduce the risk of new intramammary infections at dry-off[79(p6500)] with one study demonstrating infection was reduced by as much as 25% when sealants were used on their own and by 48% when combined with antibiotic DCT.[93(p1)]

In recognition of the role sealants can play in antibiotic reduction, a team of bovine mastitis experts proposed that, as part of the Pan-European agreement on antibiotic use in dry cow therapy, internal teat sealants be used on all cows on all farms in Europe, and in combination with antibiotic dry cow therapy when there is a high risk of infection.[81(p11),94]

The literature indicates so long as the cow's somatic cell count is consistently below 200,000 for the last three months of testing and she has not had clinical mastitis during the lactation, selective DCT along with a teat sealant is a viable option to decrease AMU. Kabera's review of the literature demonstrated that selective DCT is as efficient as blanket DCT when an internal teat sealant is used and can decrease AMU by 66%.[95]

However, even in well-managed facilities that are prime candidates for selective DCT, a small study of Irish farmers indicated there is occasionally reluctance to implement selective protocols as, among other reasons, the perceived risk of mastitis is not a risk producers are comfortable taking.[96] This perception is likely echoed in other countries where selective DCT is not the norm.

Interestingly, many Canadian dairy farms could qualify for selective treatment protocols given somatic cell counts of almost all milk tested monthly between October of 2020 to March of 2022 were below 200k cells/ml.[97] Canada's improved herd health and thus lower SCC rates in recent years are likely a function of several factors working together to encourage improvements in farm and animal management practices, including:

- Dairy Farmers of Canada's banning and penalizing milk for sale from farms where somatic cell count exceeds 400k cells/ml[87]
- The financial incentive that comes with qualifying for less expensive selective DCT (reduced AMU cost)
- The adoption of robotic milking systems (see next section)
- New facilities built to accommodate cow comfort and more appropriate pen/herd sizes which, along with good management practices, may in turn improve sanitation and cleanliness (and thus reduce infection and somatic cell count levels).

These results and measures suggest Canada's dairy industry is in a strong position to roll out selective DCT on a larger scale (should herd and individual cow SCC and clinical mastitis histories continue to qualify) in an effort to assess its effectiveness to reduce mastitis and AMU and to better educate farmers on its benefits.

On March 30, 2023, an update to the 2009 National Farm Animal Care Council (NFACC) Code of Practice for the Care and Handling of Dairy Cattle was released. It goes into effect April 1, 2024, although some requirements do not have to be implemented until 2027 and 2031.[98] Section 5.6 addresses the prevention and treatment of mastitis but the only requirement is that an analgesic be used in the treatment of cows with severe, acute clinical mastitis. The recommendations include a post-milking teat dip, cleaning and drying teats before milking, and a clean environment and dry bedding to promote cow cleanliness. Sealants, while addressed in the Code's introductory paragraph to section 5.6, are not included in the requirements or recommendations, nor are the gradual, selective dry-off techniques. This omission is a missed opportunity to address the linkages between animal welfare, disease and AMU.

Robotic, automated milking systems (AMS)

The literature confirms that herd size is a factor contributing to antibiotic use on dairy farms. A Finnish study found farms with larger herds tend to use blanket DCT and automated milking systems (AMS).[13(p7489)]

As an alternative to conventional milking parlours (where cows are moved to the parlour for milking), robotic automated milking systems (AMS) allow cows to voluntarily access the in-barn milker when they choose, requiring little to no human intervention. AMS have been growing in popularity globally[99] and sales in Canada continue to rise, with year over year growth over the past five years in BC, Alberta and Ontario. In Alberta, 23% of all dairy farms in the province are now using AMS. In Ontario, 558 of the 3300 farms (~17%) have converted.[100]

Robotic machines offer benefits of reduced labour and animal handling and computer accuracy in monitoring somatic cell count and udder health. This is particularly beneficial during times of skilled labour shortages.[100] Any data collected from the robot regarding ill health or high bacteria counts will alert farmers and their veterinarians who can then visibly check and address any mastitis concerns. Along with other housing environment and sanitation practices (to be discussed), AMS could potentially support reduced AMU and implementation of selective DCT.

Photo: Cow voluntarily milked by robotic milking system, Ontario, Canada. 2023
Credit: Trevor DeVries

Robotic systems work best by allowing cows to freely access the machine when they choose. Food rewards often serve as motivation to be milked. However, adoption of these systems may pose a barrier for many Canadian farms as tie-stalls (where cows are tethered to a stall railing) are common. Without freedom of movement, the animals cannot independently access the robot unless manually untethered.

According to Agriculture Canada's "Lactanet" 2021 report, of the 5,550 dairy farms enrolled in the milk recording program that do not use robotic milking systems, nearly 73% of farms operate tie-stall barns. Of the 991 barns that do operate robotic milking systems in Canada, 92.5% operate free stalls where cows are free to roam within the barn.[101]

It appears robotic systems encourage more farms to adopt free-stall and loose housing practices which offer cows health and welfare benefits (exercise, socializing, freedom of movement). In addition, robotic systems reduce foot and leg injuries (by eliminating transit to the parlour), reduce infections (due to improved cell count monitoring) and reduce labor costs. Furthermore, the cows themselves benefit from a sense of self-control over when they are milked.[102]

The 2023 Dairy Code does not address the health and welfare benefits (and related AMU/AMR concerns) of different milking systems such as those provided by in-barn AMS. It only requires milking equipment be properly maintained and calibrated, and recommends the area be low stress and the time cows spend away from feed, water and resting be minimized.[98]

The Code does mandate a partial tie-stall phase-out. As of April 2024, any newly built barns are prohibited from continuous tethering to tie-stalls. For older barns using tie-stalls, the Code requires elimination of continuous tethering starting April 2027 and recommends 50 hours of outdoor access within any given four-week period, weather permitting.[98(pp14-15)] These changes will hopefully result in improved health, increased use of AMS and thus reduced AMU.

Housing environment and sanitation practices

The housing environment is an important factor in controlling mastitis and other infections in dairy cows.

Bedding

A key sanitation measure is the material used for stall bedding. Sand is an inorganic material, meaning it does not contribute to bacterial growth and thus reduces infection risk.[103] It is therefore a preferred lying substrate compared to other bed and flooring substrates used in the dairy industry such as rubber mats and mattresses and organic materials such as straw, concrete, wood shavings and sawdust.[104] The wear and tear from sand on the manure and milking equipment could increase maintenance costs and affect lifespan of the machinery;[105,106] however, there are economic benefits in terms of good udder health and cow comfort[103(p3)] which could exceed minor maintenance repair costs.[107]

The new Dairy Code *requires* that cattle have a resting surface with bedding that provides comfort, insulation, dryness and traction – but does not mandate a specific type of bedding material. However, it does *recommend* that sand be used (particularly in summer) and straw in winter months (for insulation) but producers are not required to comply with Code *recommendations*. Interestingly though, the use of sand is addressed in the Section 2.8 – Bedding Management, in Section 5.1.1 – Cattle Cleanliness, and in Section 5.7 – Promoting Optimal Foot and Leg Health, but not in Section 5.6 – Preventing and Treating Mastitis. Alas the connection between the substrate choice and mastitis control is not immediately apparent. More explicit language within the Code linking housing improvements with disease prevention and mitigating AMU would be beneficial.

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Stall size and facility age

The size of today's dairy cow also contributes to a number of health and welfare issues. Better nutrition and genetic selection have resulted in larger cows producing higher milk yields[108] and breed selection has favoured higher milk producing Holsteins over Jersey and Guernsey breeds typically used over 50 years ago.[109]

As older dairy farms built 30+ years ago were intended for smaller cattle, the larger modern dairy cow may not have adequate stall space in these facilities. Consequently, older barns are in need of significant renovations to ensure cow comfort and sanitation measures. Canada's FAAST initiative notes that stocking density has a significant impact on disease levels, productivity and animal welfare due to the additional stress levels and thus weakened immune systems presented by crowding and the lack of dry, comfortable resting areas.[110] New facilities with improved ventilation, technology and equipment could also reduce other health and disease concerns and thus allow for reduced AMU, although the investment cost is a barrier for most farmers.[111(p7)]

Section 2.6 of the 2023 Dairy Code addresses space allowances for free-stalls and bedded packs (loose housing on sawdust, woodchips or wood shavings). It requires that stall sizes be "compatible" with the size of the cow and increased stall space to be phased in over the next eight years. As of April 2027, the Code requires a free-stall stocking density not to exceed 1.1 cows per stall and to no more than one cow per stall by 2031. Efforts to encourage faster adoption of increased stall space would be beneficial.

Flooring

Overall cleanliness of flooring areas is also important. A 2013 Dutch study found frequently cleaning floors more than four times per day (with an automated scraper) versus once a day helps to reduce clinical mastitis.[91(pp2930, 2934-2935)] Section 2.1 and Section 5.1.1 of the Dairy Code *recommends* (but does not require) scraping and flushing of alleyways 2-3 times per day.

The Dairy Code addresses many animal welfare inadequacies, mostly through optional recommendations as opposed to requirements, however it does not address reduced AMU/AMR or selective DCT specifically as desirable outcomes of good animal health and welfare practices. Given the interconnectedness of animal welfare and AMU, the omission of these linkages in the dairy and all other Codes of Practice appears to be a missed opportunity for AMU education and reduction.

proAction and the dairy code of practice

Although the Code does not include any penalties for non-compliance directly, animal care requirements will be incorporated into the Dairy Farmers of Canada's proAction program which does monitor and incorporate a mechanism to penalize for non-compliance.

proAction is based on the 2009 Dairy Code of Practice and stipulates that farmers must respect the Codes.[112] Under proAction, farms are inspected every two years for six key requirements addressing milk quality, food safety, animal care, livestock traceability, biosecurity and environment.[113] If non-compliance is encountered, corrective actions, fines, penalties, and milk license suspension can occur.

While proAction does require records of medical treatments given to animals to protect food safety, and its biosecurity measures address preventing diseases from coming onto farms, proAction does not explicitly highlight concerns regarding AMU/AMR as it is currently beyond proAction's mandate and jurisdiction. But given proAction is already recording antibiotic residues in milk, it seems not tracking AMU at the farm level as part of the proAction program is another missed opportunity.

More frequent inspections, video surveillance monitoring and increased penalties are needed to provide the necessary oversight.

The ProAction program, however, does not guarantee 100% compliance. A 2016 inspection by the BC Milk Marketing Board found 27% of BC dairy farms still failed to comply, reporting excessive overcrowding, cows laying on concrete (no bedding), lame or soiled cattle, tails that had been torn, and dehorning and branding of calves performed without pain medication. Furthermore, follow-up inspections showed 10% of non-compliant farms still had not implemented the corrective actions required.[114] More frequent inspections, video surveillance monitoring and increased penalties are needed to provide the necessary oversight.

Vaccines in lieu of AMU

Another useful component to reducing AMU for mastitis is the implementation of vaccine programs. There are numerous vaccines both commercially available and being trialed to control the organisms that create mastitis.[115] However, some feel the effectiveness of mastitis vaccines is not yet satisfactory[116] although progress is being made against 75% of the important causes of mastitis.[117]

Photo: Dairy cow with red, swollen teat and very full, heavy-looking udder, Quebec, Canada. 2022
Credit: Julie LP / We Animals Media

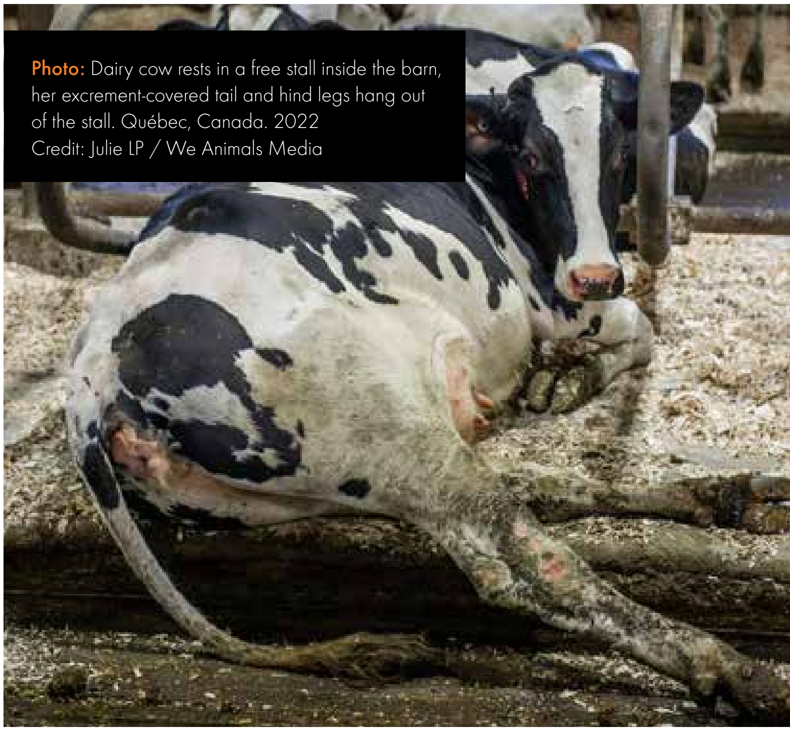

Photo: Dairy cow rests in a free stall inside the barn, her excrement-covered tail and hind legs hang out of the stall. Québec, Canada. 2022
Credit: Julie LP / We Animals Media

Summary – recommendations to reduce AMU in the dairy cattle industry

The focus on high milk yield, larger herd sizes, and reduction in labour resources, along with small and unsanitary stall and housing environments, has resulted in the convenient reliance on antibiotics to prevent intramammary infections in dairy cows.

Photo: Dairy cow on Québec dairy farm looks intently into the camera. Québec, Canada. 2022
Credit: Julie LP / We Animals Media

Improvements in basic animal management practices and housing could play an important role in reducing and eliminating the use of antibiotics, including:

1. Adoption of selective dry cow therapy in low risk herds (in lieu of blanket approach)
2. Promotion of gradual dry-off procedures through unrestricted feed rations combined with a reduction in feed energy density to reduce milk production and thus speed up teat closure
3. Application of pre- and post-milking teat dips for improved sanitation
4. Administration of teat sealants for cows with slower, inadequate teat closures
5. Increase stall size to accommodate full body length at rest
6. Provision of sand bedding in stalls to inhibit bacterial growth, and clean, dry straw bedding in winter months
7. Frequent cleaning of floors and alleyways (3x/day minimum)
8. Encourage use of vaccines in lieu of antibiotics
9. More frequent monitoring of farms through appropriate means (e.g. on-site inspections, video surveillance) to ensure compliance to Dairy Code of Practice, proAction and other industry regulations
10. Conduct a study of Canadian dairy herd practices to provide an updated benchmark from the 2015 study data and indicate impacts of 2018 regulations, particularly on mastitis tracking and adoption of selective DCT practices
11. Track AMU at the farm level and include references to AMU/AMR (and welfare practices to mitigate their occurrence) in proAction and the Dairy Code
12. Invest in and direct government and marketing board funding toward new barn construction to improve ventilation, cleanliness and overall health and welfare of dairy cows.

Photo: Cattle crowded in an indoor feedlot to be fattened before slaughter, Quebec, Canada. 2022.
Credit: Jo-Anne McArthur / We Animals Media

Protein production – Beef cattle

Beef industry overview

The number of beef farms in Canada decreased by half between 1996-2016 (from 103,673 in 1996 to 53,837 in 2016) and saw a move away from individual, smaller farms to larger centralized locations in Saskatchewan (12,428) and Alberta (17,022) which, combined, accounted for almost 55% of Canada's beef herd in 2016.[118]

Of the 12.6m cattle and calves raised in Canada in 2021, 3.78m were beef cows, of which 3.2m were fed/finished beef cattle (i.e. cattle fattened in a feedlot before slaughtered for meat).[119] Canada is one of the largest exporters of red meat and livestock, exporting 49.7% of beef and cattle produced in 2021 (valued at $4.45b), 69.9% of that to the US.[119]

According to the 2021 Census of Agriculture in Canada, of the 60,697 beef farms, the majority are small, raising an average herd size of 69 animals, with only 1% of farms (accounting for 13% of all beef cattle) raising more than 500 cows.[119]

A significant amount of research on AMU in the beef industry has focused on feedlots where disease challenges are greater due to stress from activities related to transport, stocking density and co-mingling of unfamiliar animals in pens.[121] As well, stress and disease occur from the dietary transition from forage (pasture grasses) to 90% high-grain diets if done too quickly, (grains are the feed of choice at feedlots because they result in more rapid weight gain and more tender, marbled meat).[122] However, the literature indicates some of the stress and resulting vulnerability to disease at the feedlot can be mitigated by making changes at the beef ranch, namely in weaning practices.

Weaning

One of the most stressful times for beef cattle occurs at weaning. Calves are typically abruptly separated from their mothers and shipped to a feedlot (often via an auction lot) where they are mixed with unfamiliar animals and switched to a grain diet to promote weight gain.

Photo: Cow with her calf.
Credit: Shutterstock

Upon arrival at the feedlot, they will usually receive an ear-tag, hormonal implant, vaccination, and a topical parasite control.[123(p2)] They may also be castrated and dehorned if not previously conducted at the ranch,[124] although alteration practices are typically performed by ranchers before the calves are three months old.[125,126]

The combination of abrupt weaning off milk, separation from the dam, and stress from other management practices, causes cortisol levels to spike (a contributing factor to disease). Furthermore, pain can reduce interest in eating. Cattle are thus left highly vulnerable to a host of infections, the most critical being Bovine Respiratory Disease (BRD).[127]

While transport of calves to the feedlot has historically been considered the leading risk factor for BRD (referred to as transport or shipping fever), further analysis has demonstrated the abrupt weaning process is the real concern. Weaning stress on calves causes them to lose weight and is an important contributor to the number of calves that get sick after weaning.[128] This has led some in the industry to suggest it should be referred to instead as "weaning fever" (Dr. J. Stookey, PhD, email communication, January 25, 2022).

To control infection and disease spread in cattle, researchers have found reducing stress associated with the weaning process by "preconditioning" calves prior to transport as a good start to improving animal health and welfare. Preconditioning calves involves a number of on-farm practices prior to transport to feedlots such as extended weaning times, training to eat from a feedbunk, administration of vaccinations, castration, dehorning and parasite treatment. However, the most important practice appears to be a two-step process whereby the calf is weaned off its mother's milk but remains in physical contact with her using an anti-suckling device or nose paddle/flap.[124]

The temporary flap prevents the calf from teat suckling while it remains with the dam, but does not interfere with eating, enabling the calf to transition to forage. The paddle is removed after 4-7 days when the calf has fully transitioned from milk to the new diet.[127(p65)] The practice has the added advantage of transitioning to forage before arriving at the feedlot.

The second step in the process is to separate the mother and calf physically, but still allow them to see, hear and smell each other. This is accomplished through fence-line weaning, where they will remain on the other side of the fence from each other for 3-4 days. A 2017 survey of western Canadian cow-calf producers reported "over 34% of respondents used fence-line weaning and almost 12% used two-stage weaning".[127(p65)]

One study showed 97% less vocalizing by calves which meant they spent 30% more time eating and spent 61% less time walking. Even the dams were less stressed, demonstrating a reduction in vocalizing by 84%, 60% less time walking and 13% more time lying.[127(p65),129]

In addition to lowering stress levels (which implies stronger immune systems, thus lowering possibility of infection), preconditioning and two-step weaning have been shown to result in economic advantages such as higher weight/price at slaughter, and lower morbidity, medical costs and mortality, but it depends on how those costs are shared and transferred between ranchers and feedlot operators.[130,131]

Despite the animal health and welfare benefits, some farmers are still reluctant to precondition as they do not see the financial benefit[132] or have the time, facilities and labour resources to accommodate the extended weaning period. The bottom line is it costs ranchers money to keep the calves for longer periods.[133] However, comments from farmers who have implemented the two-step weaning using nose flaps say they have been highly successful as disease and treatment is now negligible.[124]

Preconditioning and two-step weaning of calves could allow for the prudent reduction in AMU for BRD prevention, although by how much it would be reduced, and to what degree this would impact AMR, is unknown without further study.

Photo: Cattle crowded together in an indoor feedlot, Québec, Canada. 2022
Credit: Jo-Anne McArthur / We Animals Media

Mixing

The mixing of newly weaned animals at auction sites and upon arrival at feedlots poses a significant risk for the spread of disease and is the biggest risk factor for BRD.[127,134] Given high-risk animals are incubating disease when they arrive at the feedlot[135], antimicrobials are typically administered via a one-time injection (metaphylactic treatment).[136] Although the use of medicated feed requires less labour, a one-time metaphylactic injection may not contribute as much to AMR as medicated feed administered over an extended period of time and could thus be a preferable approach.[137]

Liver Abscesses

Secondary to BRD health concerns at feedlots are acidosis, liver abscesses and bloat from feeding cattle high grain diets. A cow's natural diet is composed of forage (pasture grasses) but when they are moved to a feedlot, they are transitioned to an 80-90% high grain diet consisting of corn, soy, barley, wheat and other grains.[138] Grains encourage weight gain, and thus became the preferred food source despite their conflict with the internal rumen environment of cattle if transitioned too quickly to the new feed source.[139]

Since the 1960s, feedlot operators turned to in-feed antibiotic controls such as tylosin (brand name Tylan) to reduce the severity of liver abscesses in feedlot cattle.[140] Tylosin was originally developed to improve weight gain in pigs and chickens.[140(p2)] Increases in weight gain were also found in cattle during feeding trials, as it likely reduced severity of liver abscesses that may have negatively impacted feed intake and weight gain.[140(p2),141]

Between 2008-2012, a study was conducted of 2.6 million cattle across 36 feedlots in Western Canada representing 21.5% of fed cattle in Canada. In-feed antibiotics were given to 97% of Canada's feedlot cattle, almost half to prevent liver abscesses. Because these antibiotics were used every day over a long period of time, they accounted for 83% of medically important antimicrobial use in feedlot cattle (87% of which would be classifed as 'medium importance' according to WHO).[142,143]

In-feed antibiotics were given to 97% of Canada's feedlot cattle, almost half to prevent liver abscesses. Because these antibiotics were used every day over a long period of time, they accounted for 83% of medically important antimicrobial use in feedlot cattle (87% of which would be classifed as 'medium importance' according to WHO)[142,143]

Cattle are also prophylactically treated with tylosin because abscessed livers are not suitable for human consumption so are discounted or condemned at slaughter, resulting in lost profits for operators in Canada estimated as high as $60m per year.[123(p2)] In North America, liver abscesses are found in 10-20% of beef cows, but can be higher at some feedlots and in some breeds.[123,144] According to the 2016/17 audit of Canadian beef plants, over 20% of livers were condemned at slaughter due to abscesses.[145]

Tylosin is commonly fed throughout the feeding period in Canada, the US, Mexico and Australia; however precautionary concerns over AMR led to its ban as a growth promoter in the EU in 1999, and in Brazil in 2020.[140,140(p8),146,147]

Tylosin is a macrolide and Level II antimicrobial. Macrolides are critically important in treating foodborne illnesses such as campylobacter in humans.[140] Although tylosin is not used in human medicine, tylosin cross-selects for possible resistance with other antimicrobials in this family that are used in human medicine, such as erythromycin.[123(p2)]

Cazer's 2020 review of the scientific literature – covering 13 studies that investigated the effects of tylosin on AMR – found that even "when fed at approved dosages for typical durations, tylosin increases the proportion of macrolide-resistant enterococci in the cattle gastrointestinal tract, which could pose a zoonotic risk to human beef consumers."[140(p2)] Although other researchers have stated there was no conclusive evidence of AMR from tylosin use, there was sufficient evidence to suggest it could have an impact. Thus, the cautionary reduction or elimination of it would be prudent until more is known. Although shortening the duration of its use may lead to more severe liver abscesses, its continued use does not lessen the prevalence of abscesses generally, and its overall impact is minimal on morbidity, mortality, animal performance and carcass traits.[123(p8)]

Alternatively, vaccines are available to prevent acidosis and abscesses,[144 144,148] and a diet higher in forage with less grains would help lessen abscess severity.[149] However, slower weight gain and profit losses would result by withdrawing or reducing tylosin and increasing the proportion of forage in the ration – economic considerations for feedlot operators unless commensurate price increases are passed along the supply chain to consumers.

It appears gains in carcass weight come at health costs to the animals. While feed efficiency and profits drive current animal management and treatment practices, good animal welfare is a value important to consumers and, increasingly, businesses and investors.[150] Canadian consumers have indicated in numerous opinion polls over the years they are willing to pay more for animal products if they are the result of improved animal health and welfare and reduced antibiotic use.[151-153] Thus, changes that promote animal welfare while reducing antibiotic use are positive outcomes that can be communicated externally to stakeholders and should not be disregarded.

Industry structure and logistics issues

The logistical and structural nature of the beef industry is another contributor to disease spread. Of the approximately 60,000 beef producers across Canada, most are in Alberta (40%) and Saskatchewan (31%) and many are small operators with less than 50 animals.[155] There are a total of 18 federally regulated beef processors (slaughter plants) in Canada, the majority in Alberta (6) and Ontario (5).[156] There are a little over 3600 finisher operators and less than a few hundred provincial feedlots/processors, yet 80% of the cattle raised for beef in Canada are processed in Alberta.[131] The structure of the industry results in significant mixing of various sources of animals once they enter the feedlot which research has proven hampers infection control and is a major risk factor for respiratory disease. It would be prudent for industry to re-evaluate the existing structure to determine alternative distribution and collection options, such as the use of mobile abattoirs or additional feedlots and slaughter plants, to reduce the numbers of animals being funnelled into so few locations.

Livestock auction sites present another circumstance for stress and disease spread from co-mingling unfamiliar animals. There are roughly 100 auction markets across the country.[157] As a result of the Covid-19 pandemic, producers had to find new ways to auction their animals when in-person auction sites were closed.[158] With producers gaining comfort with online technology and social media, online auctions present another opportunity to reduce mixing and thus disease and AMU.

Summary – recommendations to reduce AMU in the beef cattle industry

The practices of quick weaning, mixing of unfamiliar animals at auctions and feedlots, and feeding animals high grain diets, have resulted in the convenient reliance on antimicrobials to prevent BRD and acidosis/liver abscesses in beef cows. Improvements in basic animal management practices and structural changes in the way animals are marketed and processed could play an important role in reducing and eliminating the use of antibiotics, including:

- Implement two-step weaning process and postpone transport to feedlots until calves are older. Compensate ranchers for the extra costs incurred from the extended time calves remain on the farm
- Precondition (castrate, dehorn and vaccinate) all animals on farm (with adequate pain control and time intervals in between procedures for recovery time) prior to transfer to feedlot. Compensate ranchers appropriately for taking on costs traditionally borne by feedlot operators
- Eliminate blanket antibiotic therapy for animals arriving at feedlots in favor of selective, metaphylactic treatment of high-risk animals or therapeutic antibiotic treatment for animals showing signs of infection
- If prophylactic antibiotics are deemed necessary at the feedlot, opt for one-time or two-dose, long-acting injections versus feed-based additives
- Gradually transition from milk to forage (on farm) and adjust feed ratios at feedlot for a higher mix of forage than grains to benefit animal health (and thus reduce liver abscesses and acidosis) rather than weight gain
- Reduce the use/duration of tylosin in-feed given its minimal impact on the prevalence of liver abscesses in order to lessen its selective pressure for resistance with other medically important antimicrobials.

Our literature review has indicated the Beef Research Council, Canadian Cattle Association and many animal scientists and veterinarians concur that the time from weaning to mixing unfamiliar animals, if too short, can elevate stress/cortisol levels and are the biggest risk factors for BRD and other diseases. Although it would be challenging, some structural changes to the way beef cattle are processed in this country could also offer a path to reducing prophylactic AMU and AMR.

Alternatives over the medium and long term could include:

- Increase the number of processing plants and their proximity to beef ranches
- Increase mobile abattoirs and on-farm slaughter in multiple provinces to reduce numbers of unfamiliar animals funnelled into, mixed, and crowded at too few feedlots
- Opt for satellite and online auctions to reduce stress and disease spread from transport to/from and co-mingling of animals at auction yards.

Unfortunately, even if producers are able to reduce stress and disease on the farm through pre-conditioning, or reduce acidosis and liver abscesses through improvements in nutrition and diet adaptation, feedlot operators may still opt for blanket prophylactic antibiotic therapy due to labour shortages. Feedlot labour resources – especially trained animal health personnel – are limited in availability.[159,160]

Photo: Rows of sows confined to gestation crates at an industrial pig farm, Québec, Canada, 2022
Credit: Jo-Anne McArthur / We Animals Media

Protein production – Pork

Pork industry overview

Each year, Canada raises approximately 21 million hogs and exports to the US over five million live hogs (4m feeder pigs, 1.4m sows and boars). In 2021, there were 7,575 hog farms, the majority in Quebec, Ontario, Alberta and Manitoba. Manitoba's farms had the highest density, with the average farm housing 5622 pigs. Quebec, Ontario and Alberta housed, on average, 2351, 1439 and 1519 respectively per farm.[161]

Canada is the world's 3rd largest exporter of pork. In 2019, Canada exported 1.2m tonnes of pork (worth $4.2b) to 94 countries. In 2020, exports grew to roughly 1.5m tonnes (worth ~$5b). The top 5 export markets are China, the US, Japan, Mexico, and South Korea.[161]

The European Medicines Agency states the main disorders requiring antimicrobial use in pigs include "locomotory infections (arthritis), neurological disorders and diarrhea (caused by *E. coli*)" in pre-weaning pigs; "diarrhea, and respiratory diseases" in newly weaned pigs ("often associated with transport and weaning stress"); "respiratory (e.g. Porcine Respiratory Disease Complex) and digestive disorders (e.g. proliferative enteropathy by *L. intracellularis*, swine dysentery, ileitis, *Salmonella* spp.)" in fattening pigs; "and urogenital disorders (e.g. leptospirosis), post-partum dysgalactia syndrome and *Actinobacillus pleuropneumoniae*" in breeding pigs.[162]

As in other animal agriculture sectors, therapeutic and prophylactic AMU is common to support animal health that is often compromised by inadequate housing and management practices that prioritize economic and production interests over animal welfare.

As in other animal agriculture sectors, therapeutic and prophylactic AMU is common to support animal health that is often compromised by inadequate housing and management practices that prioritize economic and production interests over animal welfare.

To better understand AMU on Canada's pig farms, Bosman's 2022 study collected data from 25 nursery, 25 farrowing and 23 grower-finisher herds in Ontario between May 2017 and April 2018, before the December 2018 AMU regulations came into effect. Bosman's study[163] results included the following:

- "The highest quantity of AMU was administered in-feed"
- "Nursery pigs used more antimicrobials in mg/kg biomass and number of defined daily doses per 1000 pig-days, while grower finisher pigs used more antimicrobials in total kilograms and defined daily doses per pig"
- There was routine use of injectable antimicrobials of very high importance in human medicine for disease prevention, and "medically important antimicrobials were used for growth promotion in suckling and grower-finisher feed".[163]

Antimicrobials were "most commonly reported for treating *E. coli* and *Streptococcus suis* in suckling pigs, erysipelas and *Haemophilus parasuis* in sows, *Streptococcus suis*, *Haemophilus parasuis* and *E. coli* in nursery pigs, and ileitis (Lawsonia spp.) and *Mycoplasma* in grower-finisher pigs. Antimicrobials were used against a broader range of diseases in nursery pigs than in other types of pigs."[163(p5)]

Antibiotics vs. vaccination for Lawsonia intracellularis

Ileitis is the name for a common pig wasting disease known as porcine proliferative enteropathy (PPE). The bacterium *Lawsonia intracellularis* (*L. intracellularis*) is the etiologic agent of all forms of PPE.[164] The disease impacts the pig's digestion of food and nutrients and is predominantly seen in grower and finisher barns, inhibiting weight gain by 6-20% and feed conversion by 6-25%.[165]

A Canadian study modeling the typical 1,000 pigs in a farrow-to-finish operation (i.e. the full life cycle from breeding to birth to weaning to pre-slaughter) assessed the cost effectiveness of antibiotics versus vaccines for controlling *L. intracellularis*.[166]

Of the 12 health management options analyzed, four were preventative – two antibiotics (chlortetracycline and Tylosin) and two vaccines (Enterisol Ileitis and Porcilis Ileitis). Pricing for each were quoted as follows:

- Chloretetracycline (a Category III AB) @ $0.25 per pig
- Tylosin (a Category II AB that is not used in humans) @ $0.26 per pig
- Enterisol Ileitis and Porcilis Ileitis vaccines @ $1.36 and $1.38 per pig respectively.

The study calculated the costs for each of the best-, expected- and worst-case scenarios of foregoing prophylactic antibiotic use (and vaccination) and opting for therapeutic antibiotic treatment. While the best-case scenario showed annual profits of close to $90k, the expected and worst-case scenarios – with their resulting morbidity, increased feed costs, lost market weight and mortality/replacement of pigs – had severe economic consequences for producers with annual losses ranging from $13k-230k.[166(p8)] With low profit margins, based on the vaccination costs alone (given the study's calculation of $4.99 profit per marketed pig – a typical industry average in Ontario),[166(p5)] it is understandable why producers would prefer prophylactic antibiotic treatment over vaccinations and the efficiencies of scale that high-density, industrialized farming provides.

The above highlights how the majority of the industry's production-pricing model is not competitive nor sustainable given AMU and other environmental and animal welfare concerns. Producers are reliant on AMU to support industrialized production in order to meet domestic and international pricing points instead of first adopting best practices in production and vaccination and then determining price. However, companies like DuBreton[167] and Maple Leaf Foods[168] have proven they can successfully and profitably raise large numbers of pigs organically and without antibiotics for specific clientele groups. A reconsideration of the industry's strategic markets and pricing models may be appropriate to support necessary production changes and reduced AMU.

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Stress and barren environments

Barren environments restricting natural behaviours, early weaning, transport, mixing of unfamiliar animals, high stocking density (crowding) and physical alterations (tail docking, teeth clipping, castration) contribute to acute and chronic stress, compromise animals' immune systems and predispose them to illness requiring antimicrobial use.[169] However, these "generally accepted management practices" are the norm on most Canadian pig farms.

Photo: Piglets on an eight-hour long journey inside a crowded transport trailer, Saint-Isidore, Québec, Canada. 2022
Credit: Jo-Anne McArthur / We Animals Media

The role that stress plays on animals' immune systems should not be underestimated. While stress is not viewed as the main culprit requiring antibiotic treatment, stress alters homeostasis and has a domino effect on the autonomic nervous system, particularly in the case of ongoing, chronic stress.[169-171] Even short-term acute stress resulting from painful tail docking and castration raises cortisol levels.[172] Furthermore, the resulting wounds in less than sanitary environments could leave the animals susceptible to bacterial infection requiring antibiotic treatment.[169(p9),173] Other husbandry practices such as teeth clipping can result in oral lesions and exposed dental pulp that can become infected.[169(p9),174,175]

Barren, crowded environments are the norm at breeder/farrowing, grower and finishing farms.[169(p5),176] The level of stress is particularly apparent at breeding facilities where sows are confined in gestation and farrowing crates for most of their lives, unable to properly walk, turn around or perform natural behaviours.[169(p5),177] When the sow is stressed, it impacts the immune systems of her offspring, leaving them vulnerable to infection in the pre-weaning period.[169(p7),178,179] While gestation crates are being eliminated in Canada, their use may continue by a small number of producers. Certified organic and Certified Humane production systems such as those practiced at DuBreton demonstrate that more humane open pen housing with straw can be successfully incorporated even in large scale pork production.[167,180]

In addition to the stress caused by boredom and frustration from being denied their natural behaviours (physical, social and emotional needs)[169(p5)] the lack of movement/exercise from confinement results in poor heart, bone and muscle health.[169(p7),181] This leads to lameness which can lead to infrequent urination and thus reproductive and urinary tract infections needing antibiotic treatment.[169(p5),182] Barren environments in the piglet nursery – particularly the absence of straw – lowers the animals' ability to develop a circadian rhythm and can contribute to other behavioural issues such as tail-biting and belly nosing.[183,184]

Environmental enrichment

Enriching these barren environments is a crucial factor in improving the animals' overall health and well-being. Straw is a particularly desirable enrichment item, satisfying innate rooting and nesting behaviours.[185] However, the presence of mycotoxins (which can also be found in feed grain) is a concern, therefore testing straw for common moulds prior to delivery ensures bacteria does not enter the barn.[186]

Objects that are complex, chewable, malleable, ingestible and destructible encourage foraging and exploratory behaviour which can help reduce the severity of tail biting later in life[187,188] and could possibly eliminate the need to tail dock. The sensory input from the rotation of items is also important for increased interest in the object and physical activity,[189] brain development and endocrine functions.[190]

When environmental enrichment is denied, it can lead to maladaptive behaviours later in life, stress, compromised immunity, poor carcass composition and thus lower product quality.[190] Sufficient quantities of enrichment objects in different areas also divert attention away from other animals, reducing aggression and biting in pens.[190] This may have the added benefit of negating the need to tail dock, which in term would reduce stress levels and possible infections.

One study showed enrichment provides a further advantage: pigs reared in highly enriched pens showed an ability to clear the Porcine Reproductive and Respiratory Syndrome (PRRS) virus quicker and have fewer lung lesions from pneumonia than pigs raised in standard barren environments.[191] It should be noted that the pens in this study were highly enriched with twice the space as conventional pens, partly slatted and partly solid flooring, rooting material of straw, peat and wood shavings, jute bags and other novelty items. This suggests it could be in the producer's interest to incorporate some forms of environmental enrichment to improve animal health and welfare to build robustness/resilience and reduce disease susceptibility, thereby reducing the need for AMU. However, depending on the cost of inputs required to provide the enrichment, it is not necessarily an economic gain for the producer[190] (Dr. Y Seddon, PhD, Assistant Professor, email communication, June 20, 2022).

With space at a premium in intensive pig barns, producers may not embrace increased pen sizes and space per animal, but tiered flooring may address stocking density challenges while providing environmental enrichment at the same time. Researchers in Germany and the Netherlands experimented with "pig balconies" or "plateaus" at the Wageningen University

Photo: Steps on ramps enable pigs to easily walk up to the plateau for enrichment items or rest.
Credit: Wageningen University & Research

Pigs reared in highly enriched pens showed an ability to clear the Porcine Reproductive and Respiratory Syndrome (PRRS) virus quicker and have fewer lung lesions from pneumonia than pigs raised in standard barren environments.[191]

and Research facility. The separate lying, dunging and feeding platforms increased surface area by 25-40%. Closed flooring on the upper levels allows for straw while the lower floors are slatted for manure purposes.[192]

The platforms provide opportunities for social engagement and other welfare benefits to strengthen the animals' immune systems. Growth increases were distinct after 22 days and platforms provided escape areas to hide from aggressive pigs, resulting in fewer skin lesions.[193] Transport loading times for slaughter were faster due to the animals' increased leg strength and familiarity with using ramps.[194] It has been reported that multi-tiered aviaries for egg laying hens provide welfare and productivity benefits such as a reduction in undesirable behaviours, increased number and quality of eggs laid, and lower cost per egg.[195] It seems similar design elements could also improve pig welfare and productivity.

Despite the behavioural and physiological advantages straw can provide, some producers are reluctant to provide this enrichment. In addition to the mould biosecurity risk mentioned earlier, there are increased costs from labour and storage handling (Dr. Y. Seddon, personal communication, June 20, 2022) and concerns it can clog the manure slurry system and machinery used to clear manure from the slatted floors.[190]

However, there are many examples of successful straw-bedded or partially straw-based systems that show straw can be well accommodated[189(p12),196] when low quantities of straw are used in partially slatted floor systems where pigs also eat the straw (Dr. Y. Seddon, PhD, Assistant Professor, email communication, June 20, 2022). Wallgren's study of 46 nursery and 43 finishing pig units in Sweden, where 98% of the farmers used straw in slatted floor systems, indicated the majority (56% of nursery units and 81% of finishing pig units) had no manure handling problems caused by straw. Even if fixing machinery is costly and time-consuming, the maintenance costs may be reasonable when weighed against the treatment costs and production losses in the event of a disease outbreak and the public health costs of AMR.

The literature indicates providing sufficient space and complexity in housing design that favour exercise and fulfill behavioural needs is important to overall animal health and welfare and stress reduction. Progressive thinking is needed to bring forth ideas for other enrichment approaches if current materials are deemed inappropriate due to machinery conflict or sanitation requirements. Ideas could include edible objects that do not need to be sanitized in between turnover of groups of animals. Sounds, smells, and visible interest items could be presented to stimulate cognitive interest.[197,198] Variety at the feeding trough, interesting placement of food or the occasional "special treat day" could be options. These approaches are often practiced at zoos to alleviate boredom in captive animals.[199,200] Novel foods could also increase appetite and weight gain. Positive interaction with farm workers is another option that would make pigs more at ease with human handling during other processing and management practices.

Weaning and litter size

Weaning has been shown to be the most stressful time in a piglet's life.[169(p8),201,202] Offspring would naturally stay with the sow for up to 20 weeks,[169,203] but industrial systems wean piglets at 3-5 weeks. In Canada, the average age at weaning in 2020 was 21 days.[204]

Stress is exacerbated with early weaning, compromising immunity and causing diarrhea requiring antibiotic treatment.[169(p8),205] Some have suggested a minimum of 28 days is suitable to achieve maximum weight gain and immune system function, but up to 35 days while milk production from the sow remains high would allow for an easier nutritional transition.[206] An amendment to a 1991 EU Directive has required since January 1, 2013 that no piglets shall be weaned at less than 28 days unless the sow's health and welfare are at risk, or if the piglets can be moved to specialized, disinfected housing.[207,208]

A further contributing factor to compromised immune systems are breeding practices that favour large litters. Over a 28-year period, litter sizes have grown by three piglets per litter or 36% from 1993 to 2020.[209] A large litter results in differing weights of piglets – smaller piglets receive less colostrum and are thus susceptible to diarrhea, indicating low birth weight has consequences on subsequent health and mortality.[169(p7),173,210,211]

Large litters may also require the practice of cross-fostering where piglets are transferred to another sow for nursing (or to an artificial nursing system). If the fostering sow's litter was born days earlier, the youngest are particularly vulnerable to pathogen spread due to their less developed immune systems.[169(p7),212,213] Furthermore, there may be pressure to wean some piglets earlier to make room for others. When artificial systems are used, piglets are deprived of maternal contact and show signs of weakened pulmonary systems, leaving them susceptible to respiratory disease.[169(p7),214]

Summary – recommendations to reduce AMU in the pork industry

To reduce or eliminate the need for prophylactic antimicrobials, and to mitigate the risks of AMR, the following management practices are recommended:

1. Opt for vaccinations in lieu of antibiotics to reduce the reliance on antimicrobials (particularly in feed)
2. Provide enriched environments with straw for rooting/nesting and novel play/food objects to fulfill behavioural needs and mitigate biting and aggression (and thus eliminate teeth clipping and tail docking to reduce possible infections)
3. Eliminate gestation and farrowing crates in nursery barns and opt for open and large single and multi-animal pen housing to reduce sow stress levels that compromise both the sows' and piglets' immune systems, and to reduce urinary tract infections in sows
4. Lower stocking densities in finishing barns and consider complexity in housing design, including tiered balconies/platforms (for sows, weaner and finishing pigs), to reduce stress and provide exercise and social engagement opportunities
5. Delay weaning until piglets are a minimum of 28 days old to build stronger piglet immune systems, postpone mixing with unfamiliar animals and provide sufficient time between various weaning practices to reduce stress and enable full recovery after castration, teeth clipping and tail docking – practices which should be phased out.
6. Adopt breeding practices that result in smaller litter sizes (e.g. avoid selecting sows for breeding based on high reproductive prolificacy)
7. Test ways to improve human-animal interactions and investigate novelty enrichment ideas for pig farms based on practices at animal rescue shelters, sanctuaries and zoos
8. Reconsider strategic markets and pricing models that support adoption of higher welfare practices and use of vaccines over antimicrobials.

Photo: Farm in Ontario that provide enrichment and free range areas for their animals.

Photo: Pigs raised in a higher welfare system in Canada, mainly outdoors, with plenty of room to explore and root.

Photo: High welfare broiler chicken farm in Canada with space, natural light and enrichments.

Protein production – Poultry

Canada's poultry industry is comprised primarily of three supply-managed sectors – chicken (broiler meat), turkey and egg production.

Broiler chicken and turkey industry overview

Canada's poultry meat industry (chicken, turkey and stewing hens) was valued at $3.2 billion in 2020 with Ontario and Quebec accounting for 1/3 and 1/4 of chicken production respectively, and 45% and 21.1% of turkey production respectively.[215] Chicken production accounted for 89.2% of all poultry production in 2020.[216]

In 2021, there were 2823 regulated broiler chicken producers[217] and 513 turkey producers in Canada.[218] Poultry is the leading category of fresh meat sales in Canada, with sales of poultry meat in 2021 valued at Can $4.9 billion, an increase of 4.2% from 2017. In 2021, Canada exported $226 million in poultry meat, mainly to the US, with the Philippines, Chinese Taipei, South Africa and Ghana listed as the four next largest markets.[219]

Turkey production declined 4.1% in 2020 – the fourth consecutive annual decline.[216] Given the turkey sector's minimal size relative to the broiler chicken and egg industries, and declining production, turkey production is excluded from this report's discussion.

Broiler chickens

In terms of disease, "Coccidiosis and Necrotic Enteritis are two distinct but related diseases of major concern for the global broiler industry because of their ability to cause increased mortality, production losses, and animal welfare and food safety concerns. The main form of prevention has traditionally been the use of antibiotics and anticoccidials".[220]

Antimicrobial drugs have been used in ovo, feed, or water to prevent or treat commonly occurring diseases of poultry and to enable gains in productivity on farms.[221,222] *Escherichia coli*, *Campylobacter*, and *Salmonella* are the foodborne zoonotic pathogens most frequently associated with infections from poultry products.[223]

The poultry industry, despite still having significant animal welfare concerns, has been successful in reducing and eliminating prophylactic AMU in Canada. Between 2013 and 2018, the frequency of resistance to third generation cephalosporins in *Salmonella* isolated from broiler chickens and humans decreased. This was associated with the elimination of antimicrobials of very high importance to human health for disease prevention in chickens, voluntarily implemented by the Canadian poultry industry in May 2014,[12(p8),224(p1)] prior to the veterinary prescription requirement coming into effect in 2018.

CIPARS 2018 Integrated Findings report stated the reduction in ceftiofur use in broiler chicken flocks and associated overall decrease in ceftriaxone resistance in Salmonella isolates from "chickens and humans is a good example of a successful intervention to limit antimicrobial resistance". However, between 2017 and 2018, resistance to ceftriaxone increased in Salmonella isolated from broiler chickens (from 6.0% to 13.0%). This increase is being investigated and highlights the need for ongoing surveillance.[224,225] Low level ceftriaxone resistance remains despite reduction in antimicrobial use, possibly caused by some bacteria and serovars maintaining resistance genes.[225]

By 2019, resistant food-bone bacteria dropped by 38% in broiler chickens. However, the withdrawal of individual compounds, such as cephalosporins and fluoroquinolones, prompted an increase in use of and resistance levels for other lower tier drug classes, such as aminoglycosides.[226]

In May 2017, Chicken Farmers of Canada announced the chicken sector would be eliminating the preventative use of **Category II antibiotics** by the end of 2018 and set a goal to eliminate the preventive use of Category III antibiotics by the end of 2020. Category I and II goals were achieved but the elimination of Category III antibiotics has been postponed due to meeting and discussion delays resulting from the Covid-19 pandemic. The Chicken Farmers of Canada has reaffirmed their commitment though and will provide an updated timeline when available. It should be noted that only one antibiotic – bacitracin – will be impacted as it is the only Category III antimicrobial used preventively in chicken production.[227]

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Crowding and stocking density

High stocking density increases manure build-up and contributes to reduced litter and air quality, as well as increased moisture and heat.[228-231] Poor litter and air quality, high temperatures and humidity, negatively impact broiler welfare.[232,233] These also interact with other factors, including enrichment and genetics, contributing to reduced broiler health and welfare: specifically, excessive wet litter was shown to increase bacteria load in the litter,[234] and increase footpad dermatitis,[235] breast blisters and hock burns in broilers.[236] As such, it increased broiler susceptibility to bacterial infection, including experimentally-induced *Salmonella* Enteritidis[237] and necrotic enteritis.[238]

High stocking density is one of several risk factors contributing to disease susceptibility resulting in higher antimicrobial use and, although a risk, the impacts can be minimized by controlling the associated environmental parameters. Therefore, while lowering stocking density can improve health and welfare alone, it must be implemented in combination with other housing, management and genetic improvements to maximize health and welfare,[228(p1270)] and to reduce infection requiring antimicrobial treatment.

Breed

Conventional intensive indoor broiler production typically uses fast-growing breeds, defined as those with a growth rate of >50g/day. Genetic selection of broilers has led to a 400% increase in growth rate, making market weight in 60% less time than broilers 50 years ago, while the amount of breast meat on an individual bird increased by two thirds.[239] In terms of health outcomes, fast-growing breeds have more foot lesions[240-243], poorer walking ability[243-246], increased mortality, culls and indicators of poorer immunity.[241,243] Slower growing broiler breeds are those with a growth rate of <50g/day, and typically have improved health and welfare outcomes as the subsequent studies show.

Unsurprisingly, slower growing breeds have reduced antibiotic use when compared with conventional, fast-growing breeds. In 2008, the Dutch government implemented a policy to reduce the use of antibiotics in livestock by 50% across all sectors by 2013.[247] This target was exceeded, and by 2017, the sales of veterinary antibiotics had dropped by 63% from 2009 levels, which was even higher for the broiler sector with a 74% reduction, greater than all other sectors. A huge contributor to this decrease was the increasing proportion of slower growing breeds, with 36% of broiler production in the Netherlands using slower growing breeds by 2019.[248] Figure 2 (below) clearly shows the difference in antibiotic use between regular fast growing and slower growing breeds. Slower growing broilers receive less than one third the daily dose of antibiotics that conventional broilers receive. Between 91-95% of flocks (depending on the year) required no antibiotics compared with 67-79% for fast-growing broilers (Figure 2a). With the increasing proportion of slower growing broilers in the Netherlands, from 5% in 2014 to 36% in 2019, this has decreased overall antibiotic use in broilers each year, with the largest reduction coinciding with the biggest increase in the production of slower growing broiler breeds (Figure 2b).

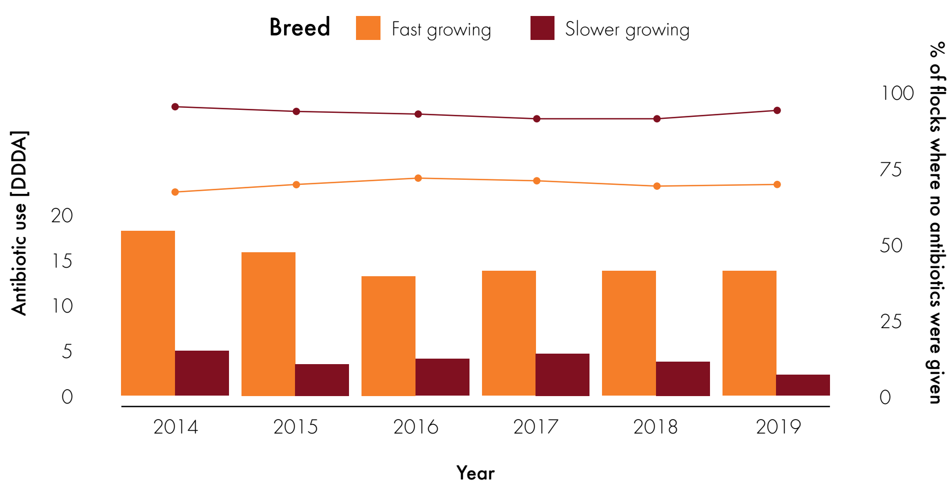

Figure 2a: Antibiotic use in average defined daily doses per animal (DDDA, bar chart, left y-axis) and the % of flocks where no antibiotics were used (line chart, right y-axis) for fast (orange) and slower growing (red) broiler breed.

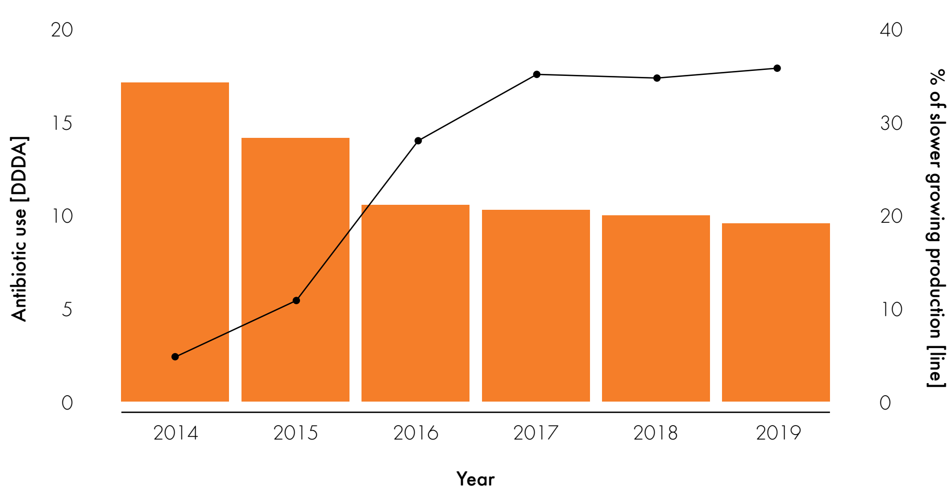

Figure 2b: Antibiotic use (DDDA, bar chart, left y-axis) and % of slower growing production (line chart, right y-axis) for all broiler production in the Netherlands. Graph adapted from data in.[248]

Production system

The main disease challenges for broilers are "gastrointestinal disorders (such as coccidiosis, necrotic enteritis, dysbacteriosis); respiratory diseases (including infections that are often followed by secondary infection with *E. coli*, such as infectious bronchitis, Newcastle disease, infectious laryingotracheitis); locomotion-related diseases (bacterial arthritis – due to e.g. *E. coli*, *Staphylococcus aureus* or *Enterococcus* spp., and secondary bacterial infections connected with tenosynovitis, necrosis of the femur head); septicaemia, and omphalitis".[162(p27)] These conditions are all associated with intensive, low welfare broiler production systems. The rise in popularity of no antibiotics ever (NAE) production provides a useful example of links between low welfare practices associated with conventional broiler production and antibiotic use. Without housing, management and genetic improvements, the removal of antibiotics for NAE production has caused an increase in disease and death on broiler farms in the US where average mortality is 25-50% more than conventional broiler production.[249] In a survey of stakeholders involved in raising farmed animals in the US, respondents indicated the decision to switch to NAE production was market-driven rather than related to human health or the health and welfare of the animals.[250] In addition, many felt that, at times, NAE production had a negative effect on animal health and welfare.

Instead of simply removing AMU from conventional production, many production systems can achieve substantial reductions through welfare improvements to the whole system. In recent years, there has been a market-driven increase in 'middle segment' broiler production systems, aimed towards moderate improvements to intensive production systems, with moderate associated increases in production costs.[251] The welfare improvements in these systems include the use of slower growing breeds with higher welfare outcomes, reduced stocking density and improved environments (environmental enrichment, air quality, litter). Increasing evidence points towards a more robust animal, less susceptible to disease with reduced antimicrobial use.[251(p8),252]

Lessons are being learned in the EU about disease prevention in a reduced antibiotic environment and some Canadian chicken farmers are taking advantage of that knowledge for success on their own farms. A case study of a Canadian broiler farm demonstrated that downtime between flocks to allow for adequate sanitation and proper temperature control in the chicks' first 10 days of life are crucial to raising a healthy flock without AMU. Farmer Alex Innes successfully produces without antibiotics 110,000 birds per cycle in three barns. He states even short-term chilling of chicks suppresses immune systems, gut health, delays gut development and lowers growth rates. Thus, keeping chicks close to heat sources and promoting socialization and preening all help to improve flock immunity. Closely monitoring water consumption, water pressure and height placement of nipples are also key.[253] Innes reported that regularly and consistently spending time in the barn, monitoring all facets of the animals and their environment, is critical.

Another Canadian case study indicated a focus on strong animal husbandry – particularly gut health, water quality and air quality – helped farmer Nathan Marten eliminate Category III antimicrobials from his operation. Smooth, soft, clean, fresh bedding and high air quality was important to reduce pathogens. Marten states the first three days after chick placement are the most important, particularly feeding chicks a few meals immediately after placement. Clean water lines and elimination of air drafts to ensure consistent air flow also improved flock health.[254]

Conclusions of a literature search on the association between AMR and organic farming compared to conventional farming in poultry by a working group of the European Medicines Agency (EMA) and European Food Safety Authority (EFSA) follow.[162] The research conducted investigated *S. aureus* in samples from humans, broilers and meat at the point of retail,[255,256] *E. coli* and *E. coli* producing extended spectrum beta-lactamase (ESBL) – an enzyme that makes the germ harder to treat with antibiotics – in poultry products,[256-259] *Campylobacter* spp. in caecal pools, intestinal tracts, carcasses, faeces, and poultry products,[258,260-264] *Listeria monocytogenes* in meat at the point of retail,[256] *Salmonella* spp. in chicken products, litter/water/food samples, carcasses at the point of retail, and faeces[258,264-266] and *Enterococcus* spp.[267]

The key finding from this review was that "*In the majority of studies, an association was observed between organic farming and reduced AMR*".[162(p5)] Since this EMA/EFSA literature review was conducted, a few additional studies have investigated *E. coli* and *E. coli* producing ESBL in relation to alternative broiler production systems. Broilers from antibiotic free and organic farms had less antibiotic resistant *E. coli* than animals from conventional farms, when measured in gut,[268] cloacal and skin[269] samples.

Summary – recommendations to reduce AMU in the broiler chicken industry

To reduce or eliminate the need for prophylactic antimicrobial use, and to mitigate the risks of AMR, the following management practices are recommended:

- Reduce stocking density
- Use slower growing broiler breeds known to have higher health and welfare outcomes
- Adopt multiple housing, husbandry and management improvements present in alternative production systems
- Institute a 10-day turnover period between flocks to properly enable sanitation measures and barn/litter dry out, and provide fresh, clean bedding
- Closely monitor and adjust water consumption, pressure and nipple height
- Ensure chicks remain close to heat sources to prevent chilling and thus support immune system and gut health
- Feed chicks a few meals immediately upon placement in the barn
- Regularly conduct in-person monitoring of the barn environment (particularly temperature control, water quality, and air quality/ventilation) and animal behaviour patterns.

Photos: Broiler chickens on a high welfare farm in Ontario, Canada. Chickens are provided with ample room, natural light and enrichments including perches and swings.

Photo: Hens on a cage-free egg farm in Canada. Hens are housed in an aviary with multi-tiered perches and nest boxes.

Egg industry overview

In 2021, there were 1205 registered egg farms in Canada generating $1.4 billion in cash receipts.[270] The egg industry has made good progress with its AMU reduction and transition toward more humane husbandry practices such as cage-free (free-run, free-range) production, including organic and pasture-raised hens. As of 2021, of the 26.57 million hens in production, 57% are housed in battery cages, 27% in enriched colony housing and 17% in free-run, free-range or organic production systems.[271] The province of BC has led the way with 30% of hens now raised in free-run, free-range and organic production systems.[272] The Canadian egg industry is on track to phase out battery cages completely by 2031, five years earlier than required by NFACC's Code of Practice for Laying Hens.[271(p14)]

A 2021 study by Agunos reports that the most common food borne disease concerns of egg-laying hens involve enteric pathogens and systemic bacterial infections (salmonellosis and campylobacteriosis) and respiratory disease. However, he found very little surveillance data concerning AMU and AMR in the Canadian egg industry. That which does exist indicates there are low and relatively stable reproductive disorders of bacterial etiology in Ontario and Quebec (the largest egg producing provinces) thus suggesting minimal AMU is required.[273] Sanitation and food safety measures such as the Start Clean-Stay Clean program and Animal Care Program by Egg Farmers of Canada endeavors to prevent outbreaks.[271(pp11-12)] However, it is well-documented that human cases of salmonella have been attributed to the consumption of eggs[274-276] and thus surveillance data is needed. The Agunos study found evidence that *E. coli* and campylobacter resistant to multiple antimicrobials were present in layer flocks in Canada.[273(p27)]

In 2020 and 2021, CIPARS collaborated with the industry to pilot on-farm surveillance of 72 flocks across Canada from BC, Alberta, Ontario and Quebec. They found "AMR was substantially lower in bacteria from egg layers than broiler chickens on farm. In 2020, the percentage of *E. coli* isolates resistant to three or more antimicrobial classes from layers was 2.5% (broiler chicken: 21%) and 24% of isolates were resistant to tetracycline (broiler chicken: 35%). Antimicrobial use records were available for nine flocks and the only reported use of medically important antimicrobials were bacitracin and tetracycline."[277] Egg Farmers of Canada has announced the launch of a pilot program to generate AMU and AMR specific data over the next three years.[271(p13)]

Given the lack of current AMU/AMR data in the Canadian egg industry, its planned launch of an AMU data tracking pilot, and the industry-wide progress on animal welfare improvements (particularly housing), further discussion on and recommendations for this sector have been omitted from this report.

Photo: Customer reviewing food labels.
Credit: Shutterstock

Protein production – Alternative models and solutions

Raised without antibiotics (RWA)

Demand for animal products from animals raised without antibiotics (RWA) is growing. Some producers, food manufacturers and retailers have responded with niche markets for these products. However, raising animals without antibiotics without commensurate housing and husbandry improvements can be problematic from a welfare perspective.[278,279] Moreover, consumers perceive that no antibiotics means healthier animals which is not always the case.[278,279]

Antibiotics have a place in animal agriculture as they do in human medicine, when used appropriately. If animals are ill, they must be treated with antimicrobials for their health and welfare. However, improvements in animal husbandry practices (stocking density, weaning periods, behavioural and physical enrichment), appropriate feed and diets to support animal health, and one-time or two-dose injections of antibiotics and vaccines in lieu of recurring feed additives will help to prevent illness and reduce the need for prophylactic AMU.

As discussed earlier in the report, companies such as duBreton and Maple Leaf Foods (and their supplier Greenfield Natural Meats) have successfully incorporated sizeable RWA programs for some of their pork and poultry farms. Major grocers such as Loblaws,[280] Walmart Canada,[281] Longos and Sobeys offer a "Free From..." line of meats.[282,283] Sobeys also offers Certified Humane and other specialty brands that don't use antibiotics (except to treat illness as needed). Metro's suppliers are encouraged to refrain from administering antibiotics used in humans as a preventative measure or growth factor. They have conducted evaluations with a large number of their meat and poultry suppliers and most meet these criteria. Metro also developed a line of organic chicken products.[284]

These examples demonstrate higher animal welfare practices are commercially viable and support the reduction and elimination of AMU on Canada's farms.

Reduction in animal numbers

An important part of the AMR solution is to also reduce the number of animals farmed. The main driver behind the current industrial scale of animal agriculture is the demand for high amounts of cheap meat.

Consumption demands for animal protein products in North America and globally are on the rise and unsustainable. According to the UN Food and Agriculture Organization (FAO), in 2018, Americans ate more meat from livestock sources, per person, than any other country in the world.[285,286] As well, industrial animal agriculture is recognized as a significant public health threat and climate risk.[287] Experts recommend reducing animal consumption (to reduce animal numbers) to help achieve our climate targets.[288,289] Significant reductions in farmed animals means more available land and other resources which would allow for farming the remaining animal numbers in higher welfare conditions. Doing so would substantially reduce AMU.[48(p27)]

Furthermore, the development of new meat, egg and dairy alternatives, and other plant-based proteins, hold promise. The innovation in this sector is predicted to grow, and consumers are already embracing these products.[290] In North America, 40% of Canadians[290] and 52% of Americans state they are now consuming more plant-based foods.[291]

A reduction in animal numbers along with more humanely raised animal proteins, cultivated animal foods and plant-based proteins all offer opportunities to mitigate AMU and AMR.

Photo: The pigs on this Canadian farm are raised in group housing in open spaces with access to the outdoors. They stay within the same group as they move through the different stages of being raised for meat.

Photo: Plant-based options.
Credit: Shutterstock

Summary – recommendations for industry and government oversight

In addition to recommended dietary shifts, policies directed at monitoring and tracking antimicrobial use on farms is essential: first, to better understand where and for what purpose they are being used, and second, to identify "where antimicrobial-stewardship efforts should be targeted to curb antimicrobial resistance".[292]

The following table highlights common diseases within animal agriculture addressed in this report and the antimicrobials currently being used in Canada to prevent and treat them, followed by animal management practices that could be implemented to facilitate a reduction in AMU/AMR.

Table 3. Summary of preventative antimicrobials used to treat common diseases in cattle, pigs and chickens, and alternative animal management practices to reduce AMU

Species	Diseases	Antimicrobials used	Alternative practices
Dairy cattle			
	Mastitis	Oxytetracycline, Cephapyrin, Ceftiofur HCl, Perlimycin, Ampicillin, Chlortetracycline	Frequent floor cleaning, improved milking hygiene (teat dips and sealants), use of robotic automatic milking systems, selective dry cow therapy using gradual dry-off and unrestricted feed with reduced feed energy density, sand and straw bedding, increased stall size
Beef cattle			
	Bovine Respiratory Disease Complex	Chlortetracycline, Oxytetracycline, Florfenicol, Ceftiofur HCl, Ceftiofur CFA	Two-step weaning process, preconditioning calves prior to feedlot (and postponing transport until older), use online auctions (on-farm) in lieu of auction yard sites, smaller groupings/limit mixing of unfamiliar animals at feedlots, one- or two-dose injections and vaccines vs in-feed antimicrobial additives
	Liver Abscesses	Tetracyclines, Tylosin	Higher levels of roughage/forage, more gradual transition to grains, reduce levels of Tylosin
Pigs			
	Respiratory Diseases	Chlortetracycline, Amoxicillin, Oxytetracycline, Penicillin G procaine, Tilmicosin, Lincomycin, Ceftiofur HCl, Ceftiofur CFA, Tylosin, Tylvalosin	Enrich environment with straw and novelty items, reduce stocking density, limit stress-inducing physical alterations (e.g. teeth clipping, tail docking, castration)
	Lawsonia intracellularis (causative agent of porcine proliferative enteritis or PPE)	Tylosin, Tetracyclines, Tiamulin, Lincomycin	Vaccines in lieu of antimicrobials, enrich environment with straw and novelty items, reduce stocking density and physical alterations, provide separate dunging areas
	Post-weaning diarrhea in piglets	Tetracyclines, Tylosin	Breed sows for smaller litter sizes, postpone piglet weaning age to a minimum of 28 days
Broiler Chickens			
	Intestinal diseases (Coccidiosis, Necrotic Enteritis)	Bacitracin, Chlortetracycline, Oxytetracycline, Tylosin	Raise slower growing breeds, feed chicks immediately upon placement, reduce stocking density, extend barn turnover time between flocks for proper sanitation, eliminate drafts, improve ventilation and heat sources
All species			
	All contagious diseases		Enhanced hygiene and cleaning, biosecurity improvements, vaccination if available and effective
	All diseases which result partially from stressful conditions or immune system challenges		Housing practices and living conditions more closely resembling natural, non-production settings

Note 1: Table adapted from Laurent, 2018[293] and CgFARAD, 2020[82] for Extra Label Drug Use published data and diseases on Canadian farms.

Note 2: As per Health Canada Drug Class categories found on the Farmed Animal Antimicrobial Stewardship Initiative (FAAST) website amstewardship.ca:
Red font indicates Category I antimicrobials of Very High Importance: Ceftiofur – a 3rd and 4th generation cephalosporin.
Orange font indicates Category II antimicrobials of High Importance: Tylosin, and Tylvalosin – macrolides, Cephapyrin – a 1st and 2nd generation cephalosporin.

There are two federal government funding initiatives which are particularly well-positioned to assist the industry in improving animal welfare practices in order to reduce AMU/AMR. Agriculture Canada has earmarked $3.5b under the Canadian Agricultural Partnership to be spent over the next five years (2023-2028) to strengthen competitiveness, innovation and resiliency of the agriculture, agri-food and agri-based products sector.[294,295]

Furthermore, $1.4b over three years has been promised to compensate dairy farmers for the impact on market share and revenue resulting from recent concessions on two key international trade agreements that will see increased foreign competition in the coming years. Dairy Farmers of Canada states these funds will be reinvested in farms to drive economic development and promote the adoption of green technology.[296] There was no mention of using the funds to invest in animal welfare improvements or to reduce AMU.

As dairy is a supply-managed industry in Canada, Canadian-produced dairy has been protected from foreign competition with tariffs applied to dairy imports, making these products more expensive and less available than Canadian dairy products. Consumers wanting to purchase higher welfare dairy products from other countries are either unable to find them on grocery store shelves or penalized with inflated prices when they are made available.[297,298] As well, dairy farmers have benefited from the uplift in the value of their quota. Quota was gifted to farmers in the 1970's and is now worth, depending on province, between $24k-$54k per cow.[299] Thus the asset value of farm with 100 cows ranges between $2.4-$5.4m. It seems the dairy industry has reaped the benefits of protectionism and quota value increases for many years. If it is to receive further taxpayer funding, producers should transition to the highest animal welfare standards desired by consumers and the requirements and recommendations stated in the Dairy Code to qualify for these subsidies.

As a condition of receiving government funding and support, the federal government should follow the lead of the EU in phasing out prophylactic use of antimicrobials in farm animals by adopting the following policies and recommendations:

AMU/AMR tracking/reporting:

- Adopt Quebec's policy of forbidding Category 1 antimicrobials for preventative purposes in food animals and only use when there is a curative need, and if no lower category treatment option is available
- Track antimicrobial sales and use in animals on farm (including ionophores) by veterinarians, pharmacies, farmers and feed mills (similar to EU programs) to fill AMU knowledge gaps (and provide data to VASR and SAVI)
- Record profits from prescription drug sales and cap veterinary monetary profits on antimicrobial sales
- Require mandatory participation by sentinel farms and vets in CIPARS
- Institute financial penalties on vets, farmers and feed mills for misuse of antimicrobials through the same mechanism CFIA uses for infractions of the food safety and other Acts
- Submit AMU/AMR data annually (or when requested) to GLASS.

Animal welfare improvements/enforcement:

- Require more humane farming methods and improved animal welfare practices to reduce AMU, particularly through decreased stocking density, extended weaning times, environmental enrichment and improved ventilation
- Supplement NFACC Codes of Practice for each species with information connecting AMU/AMR use and reduction with specific animal husbandry/welfare practices
- Develop provincial and federal animal welfare standards and monitoring programs for auction yards, feedlots and slaughterhouses and develop corresponding NFACC Codes of Practice for these sectors
- Place all recommended Codes of Practice into provincial law and ensure monitoring, enforcement and non-compliance follow-up through provincial and national supply management boards and/or quality management and assurance programs
- Promote eating less animal-sourced foods and increased production and consumption of plant-based proteins.

Photo: A young jersey calf at a farm animal sanctuary in Quebec, Canada.
Credit: Victoria de Martigny / We Animals Media

Conclusions and closing remarks

The root of the problem – Canada's generally accepted management practices

To facilitate a reduction in AMU/AMR, the literature indicates more humane animal housing and management practices are necessary to reduce pathogens and improve animals' immune systems.

In Canada, there are generally accepted animal management practices common to all farm animal species that predispose animals to bacterial illness, namely early or abrupt weaning, mixing and crowding of animals, lack of enrichment/barren environments and high growth/output demands. Within each of these practices there are further consequential practices that exacerbate the problem, adding further to excessive AMU.

At the core of most farm animal health and welfare issues causing disease and reliance on antibiotics are economic drivers. It motivates producers and feedlot operators to cut costs wherever possible to maintain affordable animal products for Canadians, and to better compete with global import and export markets.

Many of these economic drivers take the form of intensity and efficiency of scale, but more animals in smaller spaces leads to crowding, so physical alteration practices are performed to mitigate aggression and injury in these stressful conditions. Managing large numbers of animals with fewer workers dictates confinement practices, automation, and blanket prophylactic therapy of antimicrobials and other medication. Automation in some cases improves sanitation but negates visual and hands-on inspection and treatment of individual animals. Faster turnaround times from birth to slaughter dictate breeding, weaning and medication protocols to encourage weight gain in the shortest amount of time but compromise animals' immune systems. Vaccinations offer promise but they can be expensive.

In addition, there are infrastructure elements within the food industry that contribute to stress and the spread of disease, namely where mixing of large numbers of unfamiliar animals from multiple locations occurs. This is particularly true in the beef industry where over 50,000 producers must funnel their animals into roughly 300 feedlots nationwide (most of which are in Alberta). In the pork industry where, in a good year, farmers can only expect to earn $5 per animal, downward economic pressures from international markets reinforce and continue to drive even greater efficiencies of scale just to remain in business. Furthermore, government policies encouraging affordable food pricing for all Canadians, while important, is a further obstacle to enabling changes to the industrial animal production model that relies upon antimicrobial use to sustain animals lives in suboptimal living conditions. As a result of market conditions, industry practices and government policies, consumers benefit from lower food prices but the true costs are externalized: animal welfare, the environment and human health are compromised.

The consequences of AMR for human health and Canada's economy are dire. In 2018, Canadian public health experts concluded that 26% of bacterial infections were resistant to the drugs generally used to treat them, taking 5400 lives in Canada annually.[300]

If the rates of AMR to first-line antibiotics continue at 26%, by 2050, Canada could see economic losses in GDP of $13 billion annually.

If the rates increase to 40% – a likely scenario according to these experts – a further $21 billion annually will be lost (and 13,700 lives) resulting in a cumulative decline to Canada's GDP of $388 billion by 2050, solely from AMR-related issues.[300]

This report highlights opportunities to improve animal management practices on farms that would facilitate the reduction of preventative and, in some cases, therapeutic uses of antibiotics in farm animals. Implementing this report's recommendations will require buy-in from the agriculture industries, with support from government, by way of financial, regulatory and legislative measures governing animal agriculture and AMU in Canada.

If AMR increases gradually from 26% to 40%, by 2050, the *cumulative* cost to Canada is estimated at:

396,000 lives	$120 billion in hospital costs	$388 billion in GDP

Source: Adapted from *When Antibiotics Fail*. The Expert Panel on the Socio-Economic Impacts of Antimicrobial Resistance in Canada (2019).[300]

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