Technology adoption, management practices and vaccine use in Canadian cow-calf herds

A Thesis Submitted to the
College of Graduate and Postdoctoral Studies
In Partial Fulfillment of the Requirements
For the Degree of Master of Science
In the Department of Large Animal Clinical Sciences
University of Saskatchewan
Saskatoon

By

Madelana M. Lazurko

PERMISSION TO USE

In presenting this thesis/dissertation in partial fulfillment of the requirements for a Postgraduate degree from the University of Saskatchewan, I agree that the Libraries of this University may make it freely available for inspection. I further agree that permission for copying of this thesis/dissertation in any manner, in whole or in part, for scholarly purposes may be granted by the professor or professors who supervised my thesis/dissertation work or, in their absence, by the Head of the Department or the Dean of the College in which my thesis work was done. It is understood that any copying or publication or use of this thesis/dissertation or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of Saskatchewan in any scholarly use which may be made of any material in my thesis/dissertation.

Requests for permission to copy or to make other uses of materials in this thesis/dissertation in whole or part should be addressed to:

Head of the Department of Large Animal Clinical Sciences
University of Saskatchewan
52 Campus Drive
Saskatoon, Saskatchewan, S7N 5B4

OR

Dean of the College of Graduate and Postdoctoral Studies
University of Saskatchewan
116 Thorvaldson Building, 110 Science Place
Saskatoon, Saskatchewan, S7N 5C9

ABSTRACT

An understanding of current technology adoption and management practices including vaccination protocols used by Canadian cow-calf herds is important to understand current practices, identify areas for improvement, and direct extension programs. Adoption of technologies and practices that increase reproductive performance and increase production efficiency is important for the long-term economic sustainability of the beef industry. Vaccines are one of the most important tools available to cow-calf producers to control disease within and across herds, and to reduce economic losses caused by disease burden across all beef production sectors. To date, regional surveys have attempted to collect this information, but the lack of uniform data prevents the comparison of herds in different regions of the country. The aim of this thesis is to address this gap in technology adoption and record keeping data, and determine, the vaccine protocols employed in cow-calf herds across the country.

In Chapter 2, a mail survey was used to gather data regarding the different technologies and record keeping practices utilized by Canadian cow-calf producers. Survey data was returned from 131 herds across 8 provinces (91 western and 40 eastern herds). The most widely adopted practices were the maintenance of individual female production records, feed testing, and the use of an on-farm animal weigh scale. Differences between eastern and western Canadian herds were identified. Western producers were more likely to use nutritional technologies including the use of a nutritionist, feed testing and growth promoting implants in calves, while eastern producers were more likely to use artificial insemination. Large herd size (>300 cows) was associated with adoption of data collection technologies and recommended practices including use of weigh scales, RFID tag scanners, utilizing a defined breeding season, and feed testing. Similar to past reports, paper systems were the main record keeping medium. Producers who maintained

production records utilized them for culling decisions and replacement heifer selection. While adoption of many types of technology has increased across Canada, there is still room for uptake up technologies that allow for more efficient animal management in all provinces.

Chapter 3 utilized the same producer survey as Chapter 2. Vaccination protocols used in Canadian cow-calf herds were investigated as a critical herd and animal disease management tool. Viral bovine respiratory disease pathogens: Infectious bovine rhinotracheitis (IBR), Bovine respiratory syncytial virus (BRSV), Parainfluenza virus type 3 (PI3), and Bovine viral diarrhea virus Types 1 and 2 (BVDV) were the most common vaccines administered to all cattle, followed by clostridial vaccines. Use of clostridial vaccines was more likely in western herds than eastern herds. For the purpose of this study, suckling calves are defined as all calves prior to weaning. Vaccination of suckling calves against IBR/BRSV/PI3 (92%) and BVDV (78%) was common, however only 47% and 39% of calves were administered a booster for these targets respectively, prior to weaning. Calves administered a viral respiratory vaccine prior to 3 months of age were more commonly administered a second vaccine of that target prior to weaning compared to those first vaccinated after 3 months of age. Use of intranasal vaccines in neonatal calves has increased since previous reports and vaccine use across Canada generally follow veterinarian core vaccine recommendations. While vaccine use has increased across Canada, most notably in calves prior to weaning, areas for improvement remain. Vaccine protocols including number of doses and timing of delivery vary widely within and across provinces, regardless of product used and label instructions.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my supervisor Dr. Cheryl Waldner, for your unwavering support, patience, and dedication to me and this project. I will forever be grateful for the knowledge and kindness I received from you over the past two years.

I would also like to thank my committee members; Drs. John Campbell, Nathan Erickson, and Sheryl Gow who invested much time and effort into helping make this thesis into something I am proud of.

Thank you to my fellow lab members for your support and encouragement during this sometimes stress-inducing undertaking.

This project would not have been possible without all the producers who participated in this C3SN study, so for your participation I am grateful. Thank you to Sharlene April for your coordination of this project.

I would also like to thank the Beef Cattle Research Council for providing funding for this research. This project would not have been possible without your support.

Last but not least, thank you to my family and friends. You have been a rock for me during these past two years and I will forever be grateful to have such encouraging, understanding, supportive, and loving people in my life. Thank you all.

TABLE OF CONTENTS

List of Tables

List of Figures

LIST OF ABBREVIATIONS

AABP	American Association of Bovine Practitioners
AI	Artificial insemination
AMR	Antimicrobial resistance
AMU	Antimicrobial use
BCoV	Bovine Coronavirus
BCRC	Beef Cattle Research Council
BRSV	Bovine respiratory syncytial virus
BRV	Bovine rotavirus
BVDV	Bovine Viral Diarrhea Virus
C3SN	Canadian Cow-calf Surveillance Network
CI	Confidence interval
IBR	Infectious Bovine Rhinotracheitis
ID	Identification
IN	Intranasal
MLV	Modified-live vaccine
NSAID	Non-steroidal anti-inflammatory drugs
OR	Odds ratio
PC	Portable computer
PI3	Parainfluenza virus type 3
RFID	Radio frequency identification
SD	Standard deviation
SQ	Subcutaneous
VBP+	Verified Beef Production Plus
WCCCSN	Western Canadian Cow-calf Surveillance Network

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Adoption of technologies and management practices that increase production efficiency and animal health are vitally important in ensuring the sustainability of Canadian beef production. The cow-calf herd is the foundational unit of beef production, yet data regarding technology use on these operations has thus far been limited to regional surveys (1-4).

The technologies available to cow-calf producers range far and wide. Breeding and genetic technologies are available to increase reproductive efficiency and traceability; remote surveillance technologies for monitoring cattle and water systems help to reduce time and labour usage; and precision feeding technologies and practices are available to help reduce feed waste and increase feed efficiency. There are also specific management practices that can and should be used by cow-calf producers for more precise business management such as record keeping.

The use of vaccines in cow-calf herds is one of the most important animal health technologies available. Vaccines can prevent or lessen the prevalence of disease in a herd, resulting in better reproductive performance and increased economic return per head (5). Vaccination of calves in the cow-calf herd also primes the calves' immune systems for the disease challenges faced during transportation and comingling in markets and feedlots.

1.2 Objectives of literature review

Literature review objectives:

1) Understand the importance and benefits of technology adoption in the beef industry.
2) Explore existing knowledge of common technologies, management practices and vaccination protocols used in Canadian cow-calf herds.

3) Explain the importance of vaccine use in cow-calf herds and implications for calves in succeeding production sectors.
4) Describe the most up-to-date information regarding vaccination protocols used in Canadian cow-calf herds.

1.3 Technology in Canadian cow-calf herds

The adoption of technology by agricultural producers uses a diffusion model, whereby dissemination of information is critical to the adoption of new or existing technologies (6). The diffusion model identifies "early adopters" and the "early majority" as the driving force behind uptake of new and innovative practices (6). Cow-calf producers, compared to other more regulated industries such as oil and gas, have more liberty over what technologies they want to adopt, leading to slower rate of change within the industry (6). However, there are many technologies available to cow-calf producers that help to increase productivity, improve reproductive performance, and increase the environmental and economic sustainability of each operation.

To this point, regional/provincial surveys have attempted to quantify adoption of different management tools and practices (1-4, 7) by cow-calf producers. An attempt has been made to amalgamate data from the different regional surveys into comparable information (8). Numerous publications have resulted from these regional surveys and Statistics Canada data (9-13).

1.3.1 Technology adoption in Canadian cow-calf herds

Breeding technologies are intended to increase reproductive success, genetic improvement, and economic soundness. A subset of all available technologies will be discussed. A defined breeding season has shown to increase profit per head compared to a 90 day calving period (14). In previous reports, the average breeding season length for cows in western provinces, Ontario and Atlantic provinces were 86.5 days, 119 days and 136 days respectively (8). Pregnancy cheeking in cows was done by 49-75% of Canadian cow-calf producers and artificial insemination was used by 8-53% of herds depending on location within Canada (8). To date, adoption of breeding and reproductive technologies has increased across Canada (8).

Feed and nutrition related technologies can increase feed efficiency, improve productivity, reduce waste, and reduce feed cost (15). These technologies include feed and water testing, use of a nutritionist or ration balancing software and weighing bales. Previously it was reported that between 16 and 47% of producers feed tested, and up to 41% of producers tested water within the last five years, depending on location (8). Use of a nutritionist and/or a ration balancing software program to balance rations has increased in western Canada between 1997 (25.7%) and 2017 (38.1% used a nutritionist and/or 44.4% balanced own rations) (4, 7).

Remote monitoring technologies are a more novel technology which provide an opportunity to assist producers by reducing labour and time associated with monitoring cattle and water sources (16). Cameras and drones used to monitor cattle during high supervision seasons such as calving can reduce the need for personnel in the pens, thereby reducing the cost of labour and time (16). Remote monitoring technologies can also be used to study animal behaviour, health and pasture use, and also monitor fence lines and facilities (17). A 2015 study of northern Ontario and Quebec cow-calf herds found that few producers used video surveillance cameras to monitor cattle (2-5%) (1). On the whole data are scarce regarding adoption of remote monitoring technologies in other provinces.

1.3.2 Record keeping in cow-calf herds

A 2015/2016 study of Ontario cow-calf producers found of those who maintained records, 87% used paper and 20% used electronic software (3). A similar study of producers in northern Ontario and Quebec found that most producers used handwritten or paper records (80-88%) compared to electronic spreadsheets (18 %) (1). According to Pearson et al. (2019) the most common data recorded at calving in western Canadian herds was date of birth (95%), calf ID (90%), and calving ease score (74%) (12). Overall, the most common production records maintained by western Canadian cow-calf producers were calf birth date (98.6%), animal individual ID (identification) (92.8%), calf ID linked to dam's ID, culling/death loss records (91.3%), and health records (85.5%) (11).

1.4 General cow-calf vaccination guidelines and practices

Vaccination as a herd health management tool can be an effective form of disease control, reduction, and prevention (18-20). Vaccinations administered to cow-calf herds vary greatly between operations. Before the "Alberta Beef Herd Analysis" in 1998 there was virtually no information on vaccination protocols used by western Canadian cow-calf producers. The first Western Canadian Cow-Calf Survey (WCCCS) in 2014 (21) was the second attempt at documenting common vaccination practices across the western provinces. The second WCCCS in 2017 (22) surveyed 216 western Canadian cow-calf producers regarding common management practices and vaccination protocols. The results of the 2016 survey found that 95% of producers vaccinated their animals against at lease one disease or condition (22). This is similar to the 2014 vaccination rate of 91.4% (21).

The American Association of Bovine Practitioners (AABP) (2021) recommends all beef animals be administered core vaccines including Infectious Bovine Rhinotracheitis (IBR), Bovine Viral Diarrhea Virus (BVDV), Parainfluenza virus type 3 (PI3), Bovine respiratory syncytial virus (BRSV) and clostridial disease annually (23). The Western Canadian Animal Health Network (WeCAHN) identified the same target pathogens as core vaccines with the exception of PI3 (24). Vaccination protocols should differ between operations based on specific risk factors unique to each herd (23). The result of the 2017 WCCCS found that all calves were most commonly vaccinated against BVDV Type 1 or 2 (92%) (25). Calves were also commonly vaccinated against IBR, PI3, and BRSV (95%), clostridial disease (99%), and *M. haemolytica* (74%). Clostridial pathogens, BVDV and IBR were the most common targets for administration of two or more doses (25).

1.4.1 Producer motivations for vaccine use

A survey of 93 western Canadian cow-calf herds in 2016 determined the most common motivation for a producer to vaccinate their animals was the importance of disease in the herd and the economic benefits of using the vaccine (25). Producers reported using vaccines to prevent respiratory disease from reoccurring in their herds and prevent reproductive disease from entering their herds (25).

1.4.2 Vaccination of cows in western Canada

A 2016 survey of Canadian and American cow-calf veterinarians reported the most common vaccination recommendations included IBR, BVDV Types 1 and 2, leptospirosis, PI3, BRSV and vibriosis (26). Waldner et al. (2019) reported most Canadian cow-calf producers (97%) vaccinated cows with at least one product, and the most common vaccine targets were respiratory disease and calf diarrhea (25). Most herds vaccinated cows prior to breeding season (April-June) and used a modified-live vaccine for viral respiratory targets including BVDV (27). The WCCCS II reported cows in western Canada were most often vaccinated for reproductive disease (84%) and BRD (75%), followed by scours (66%) and clostridial disease (62%) (22). Producers reported the most common reason for not vaccinating cows was because they had a closed herd (55%) (22). Comparatively, a 2017 study of United States cow-calf herds reported vaccinating cows most often for Leptospira (46%), PI3 (39.5%), BRSV (39.3%), and IBR (38.4%) (28).

1.4.3 Vaccination of bulls in western Canada

A survey of Canadian and American cow-calf veterinarians determined that 79% of veterinarians recommended vaccinating bulls at the same time as cows (26). The WCCCS II (22) found that bulls in western Canada were the least likely to be vaccinated compared to other animals in a cow-calf herd. Waldner et al. (2019) surveyed 93 cow-calf producers in western Canada and noted that bulls were most often vaccinated before the breeding season (April to June) and a modified live vaccine was the most common form used to protect against BVDV and other respiratory pathogens. Producers chose to vaccinate bulls with at least one product in 72% of herds. Bulls were commonly vaccinated for BVDV (55%) and IBR (55%), and were rarely vaccinated more than once per year (27).

1.4.4 Vaccination of replacement heifers in western Canada

From a 2016 survey of western Canadian cow-calf herds, Waldner et al. (27) reported heifers were commonly vaccinated before breeding between the months of January and March. The most common vaccine targets were reproductive and respiratory diseases such as BVDV (96%) and IBR (96%) (27). There was no difference in the proportion of herds reporting the use of a modified live vaccine (MLV) or an inactivated vaccine (27). Respondents to the WCCCS II reported vaccinating replacement heifers most often against reproductive disease (82%), clostridial disease (80%), BRD (76%) and scours (57%) (22). Waldner et al. (27) reported cow-calf producers were likely to give boosters or second doses to replacement heifers for the prevention of scours in calves. Producers also reported administering pre-breeding vaccines to replacement heifers between the months of January and March (27).

1.4.5 Vaccination of suckling calves in western Canada

A survey of 139 Canadian and American bovine veterinary practitioners found that 90% of veterinarians recommended a MLV for suckling calves and 10% recommended an inactivated vaccine (26). The most common vaccines recommended to producers for calves were IBR (99%), BRSV (98%), BVD type 1 and 2 (96%), and PI3 (93%) (26). Respiratory vaccine recommendations were closely followed by clostridial disease (77%) and *M. haemolytica* (77%) (26). Waldner et al. (27) reported the most common vaccines administered to western Canadian calves protected against clostridial disease (97%), viral reproductive and respiratory pathogens including BVDV, IBR, PI3, BRSV (82-85%), *Mannheimia haemolytica* (67%) and *Histophilus somni* (45%). Suckling calves were most often vaccinated before summer pasture turnout between the months of April and June and the use of a MLV was more common than a inactivated vaccine for reproductive and respiratory pathogens (27).

1.4.6 Vaccination as a part a of preconditioning programs

Fully vaccinating calves in cow-calf operations before entering the market system can reduce the prevalence of Bovine Respiratory Disease (BRD) in feedlot operations (29). There is evidence to suggest that vaccination at feedlot entry has minimal effect on controlling BRD prevalence (30).

Preconditioning is a term generally used to describe a group of vaccination, management and nutrition practices performed on calves before and around weaning to improve feed efficiency, reduce morbidity and decrease treatment cost (31). Due to a lack of incentives for Canadian cow-calf producers, preconditioning programs have not been widely adopted. Full vaccination of cattle in cow-calf herds may be an effective means of minimizing or controlling BRD in subsequent production sectors (32). A recent Canadian study found that most producers use at least one vaccine on calves prior to weaning and the most common vaccine targets are clostridial pathogens followed by respiratory pathogens (27). Researchers found that respiratory vaccines were most often administered to suckling calves (55%) before summer turnout and to weaned calves (35%) at weaning (27). A 2017 study of American cow-calf herds determined that 57.5% of operations vaccinated calves before or during weaning against respiratory disease (28).

1.4.7 Efficacy of vaccinating cow-calf herds to prevent BRD in the feedlot

The American Association of Bovine Practitioners states that vaccine efficacy can be reduced when animals are under stress-induced immunosuppression (23). In the current beef production structure, most calves are vaccinated against BRD pathogens upon arrival at feedlot where stress from environmental changes, transport, and comingling with animals from other herds is high. Transferring more responsibility to the cow-calf sector to vaccinate calves against BRD pathogens could help decrease BRD morbidity in the feedlot (33). Chamorro et al. (34) determined that the vaccination of calves around time of weaning with a multivalent BRD MLV vaccine reduced BRD mortality and morbidity post weaning. A study of three different vaccination protocols used on calves entering a feedlot found that calves vaccinated for BRD 15 days prior to weaning and again 15 days prior to feedlot entry had reduced incidence of BRD in the feedlot compared to those vaccinated only once before feedlot entry and then again at entry or after entry (29).There is a large body of evidence to suggest that the most effective time to vaccinate calves to reduce incidence of BRD in the feedlot is around the weaning period. Interestingly, there is also evidence to suggest that vaccination of the dam against viral pathogens can decrease the risk of BRD related mortality of that dam’s offspring during the feeding period, signifying that vaccination of the cows and replacement heifers may also play a crucial role in feedlot disease reduction (35).

1.4.8 Efficacy of vaccination at feedlot entry in prevention of BRD

Administration of BRD pathogen vaccinations upon feedlot entry is standard practice for most feedlot operations in North America with the intention of reducing BRD morbidity and mortality(28). A recent meta-analysis by O'Connor et al. (30) critically examined 14 relevant articles for evidence of the efficacy of BRD vaccination at feedlot entry in preventing or limiting disease. The analysis determined that there is insufficient evidence to conclude that BRD vaccines routinely administered at feedlot entry are beneficial in preventing BRD in the feedlot (30).

1.4.9 Regional differences in cow-calf vaccination protocols across Canada

A 2019 Beef Cattle Research Council report compared regional herd vaccination protocols from data collected across Canada over the past two decades (8). Western Canada consistently reported general herd vaccination rates with the use of at least one vaccine above 90% between 1998 and 2017, while eastern Canada reported vaccination rates with at least one vaccine of 70% in 2016 and73% in 2017 (8). Regional surveys reported Ontario cow-calf producer's vaccination of cows against reproductive diseases: vibriosis, leptospirosis, and BVDV in 30%, 59% and 67% of herds respectively, and producers in western provinces reported vaccination of cows against vibriosis, leptospirosis and BVDV pathogens in 29%, 19% and 91% of herds respectively (3, 4, 25). In 2017, the percentage of western Canadian herds that vaccinated breeding females for scours was 66%, while 30-35% of eastern herds reported administering the same vaccine (8). Respiratory vaccines were administered to calves in Ontario and Atlantic Canada at a rate of 12% and 14% respectively, and calves in western Canada received respiratory vaccines at a rate of 84% (8). An important barrier to the direct comparison of these regional surveys is the difference in specific questions and details asked regarding vaccine use. None of the surveys provide detailed vaccine protocols used for all animals in a herd. For example, the Ontario cow-calf survey asked producers if they vaccinated their herd and for what pathogens, while the Atlantic cow-calf survey only reported if producers vaccinated their herd and if they used intranasal vaccines in calves (2, 3).

1.5 Reasons for non-adoption of technologies available to cow-calf producers

Producers are often aware of technologies available to them however, most often economic constraints may limit the uptake of different technologies (36). A study of American beef producers found that other reasons for lack of adoption were that the technologies were not applicable to their farms and that there was unfamiliarity with the technology (36). Canadian cow-calf producers identified having a “closed” herd and satisfaction with conception rates as reasons for not vaccinating breeding females against reproductive diseases, and having a “closed “herd, selling calves right after weaning, and absence of calf health problems as reasons for not vaccinating against respiratory diseases (8). The appearance of healthy cattle was the main reason that producers chose not to test water or feed sources, additionally when cattle drank the same water as producers, it was perceived to be safe without further testing (8). Producers in western Canada identified satisfaction with conception rates, lack of facilities and lack of time and/or labour as the reasons for not utilizing a defined breeding season of ≤63 days (8). The main reasons for not conducting yearly pregnancy checks were a preference to sell open cows in the spring, the producer being able to tell if the animal is pregnant, and cost (8). General reasons for not adopting more complex reproductive technologies such as embryo transfer and artificial insemination were the perceived increase in management, technical skill and labour (8).

1.6 Research opportunities

Opportunities for future research include uniform surveillance of technology adoption and vaccine use across Canada. This would provide up to date and comparable information across provinces. Understanding vaccine use by cow-calf producers would help identify areas to improve herd health and productivity, as well as increase health and reduce the use of antimicrobials in the feedlot.

1.7 Research purpose

The purpose of this research is to determine how widely technologies have been adopted, to identify areas for improvement and to describe vaccination protocols used in Canadian cow-calf herds. This project was conducted within the preestablished framework of the Canadian Cow-Calf Surveillance Network (C3SN). Surveys were sent to producers participating in the C3SN to obtain data regarding technologies used, record keeping practices, and vaccination protocols utilized in cow-calf herds across Canada. The data generated from those surveys is summarized in this thesis.

1.8 Research objectives

1) Describe technology adoption and management practices used in Canadian cow-calf herds, assess associations between herd attributes, productivity outcomes and adoption; and identify opportunities for improvement.
2) Describe vaccination protocols and factors associated with vaccine use in Canadian cow-calf herds and define associations between vaccine use and productivity outcomes.

1.9 References

1. Lamothe S and North Haven Solutions. Northern beef study: Northern Ontario and Northern Quebec beef cow-calf production. 2018.

2. Maritime Beef Council. Atlantic Cow-Calf Production Survey Aggregate Results, 2018.

3. Ontario Cow-Calf 2015/16 Production Survey (OCC). OCC: University of Guelph. 2018. Available from https://www.beefresearch.ca/files/pdf/Ontario%20Cow-Calf%20Summary%20Nov%2012%202018.pdf.

4. "Western Canadian Cow-Calf Survey II". WCCCSN. University of Saskatchewan. Available from http://westernbeef.org/pdfs/wcccs/WCdnSurveyII_FINAL.pdf.

5. The Cost Benefit of Using Vaccines in Beef Cattle. Beef Cattle Research Council (BCRC). Available from https://www.beefresearch.ca/blog/the-cost-benefit-of-using-vaccines-in-beef-cattle/.

6. Turner RJ. Diffusion of Innovations. J Minimally Invasive Gynecology 2007;14 (6): 776.

7. Alberta Cow-Calf Audit 1997/98. Alberta Agriculture and Rural Development. Available from http://westernbeef.org/pdfs/economics/AB_CowCalf_Audit.pdf.

8. Davidson TM and Canfax Research Services. Beef Cattle Research Council (BCRC): Adoption Rates of Recommended Practices by Cow-Calf Operators in Canada, 2019.

9. Waldner C, Wilhelm B, Windeyer MC, Parker S, and Campbell J. Improving beef calf health: frequency of disease syndromes, uptake of management practices following calving, and potential for antimicrobial use reduction in western Canadian herds. Transl Anim Sci 2022;6 (4): txac151.

10. Murray CF, Fick LJ, Pajor EA, Barkema HW, Jelinski MD, and Windeyer MC. Calf management practices and associations with herd-level morbidity and mortality on beef cow-calf operations. Animal 2015;10 (3): 468-477.

11. Manglai. Examining Record Keeping and Benchmarking Effects on the Production and Performance of Cow-calf Farms in Canada Saskatoon: University of Saskatchewan, 2016.

12. Pearson JM, Pajor EA, Caulkett NA, Levy M, Campbell JR, and Windeyer MC. Benchmarking calving management practices on western Canada cow-calf operations. Transl Anim Sci 2019;3 (4): 1446-1459.

13. Jelinski M, Bergen R, Grant B, and Waldner C. Adoption of technology and management practices by Canadian cow-calf producers. Can Vet J 2019;60 (3): 287-293.

14. Boyer CNG, Andrew P. and Pohler KG. Improving Beef Cattle Profitability by Changing Calving Season Length. J Appl Farm Econ 2020;3 (1).

15. Feed Quality, Testing & Analysis for Beef Cattle. Alberta Beef Forage and Grazing Centre. Available from https://www.beefresearch.ca/tools/feed-testing-analysis-for-beef-cattle/.

16. Liu C, Jian Z, Xie M, and Cheng I. A Real-Time Mobile Application for Cattle Tracking using Video Captured from a Drone. International Symposium on Networks, Computers and Communications (ISNCC) Year: 1-6.

17. Mufford JT, Reudink MW, Rakobowchuk M, Carlyle CN, and Church JS. Using unmanned aerial vehicles to record behavioral and physiological indicators of heat stress in cattle on feedlot and pasture. Can J Anim Sci 2021;102 (1): 1-8.

18. Newcomer BW, Chamorro MF, and Walz PH. Vaccination of cattle against bovine viral diarrhea virus. Vet Microbiol 2017;206: 78-83.

19. Larson RL and Step DL. Evidence-based effectiveness of vaccination against Mannheimia haemolytica, Pasteurella multocida, and Histophilus somni in feedlot cattle for mitigating the incidence and effect of bovine respiratory disease complex. Vet Clin North Am Food Anim Pract 2012;28 (1): 97-106, 106e101-107, ix.

20. Theurer ME, Larson RL, and White BJ. Systematic review and meta-analysis of the effectiveness of commercially available vaccines against bovine herpesvirus, bovine viral diarrhea virus, bovine respiratory syncytial virus, and parainfluenza type 3 virus for mitigation of bovine respiratory disease complex in cattle. J Am Vet Med Assoc 2015;246 (1): 126-142.

21. Western Beef Development Centre. Western Canada Cow-calf survey (WCCCS) Aggregate Results, 2015.

22. Social Sciences Research Laboratory. Western Canada Cow-calf Survey II (WCCCSII) Aggregate Results: Univeristy of Saskatchewan, 2018.

23. AABP Vaccination Guidelines. American Association of Bovine Practitioners. Ashland, OH.

24. Western Canadian Animal Health Network (WeCAHN). Beef Cow-calf Core Vaccines List, 2023.

25. Waldner CL, Parker S, and Campbell JR. Vaccine usage in western Canadian cow-calf herds. Can Vet J 2019;60 (4): 414-422.

26. Fike GD, Simroth JC, Thomson DU, Schwandt EF, Spare R, and Tarpoff AJ. A survey of recommended practices made by veterinary practitioners to cow-calf operations in the United States and Canada. Prof Anim Sci 2017;33 (6): 716-728.

27. Waldner CL, Parker S, and Campbell JR. Vaccine usage in western Canadian cow-calf herds. The Canadian Veterinary Journal 2019;60 (4): 414-422.

28. USDA National Animal Health Monitoring System. Beef 2017: Beef Cow-calf Health and Management Practices in the United States. Fort Collins, CO, 2021.

29. Schumaher TF, Cooke RF, Brandao AP, et al. Effects of vaccination timing against respiratory pathogens on performance, antibody response, and health in feedlot cattle. J Anim Sci 2019;97 (2): 620-630.

30. O'Connor AM, Hu D, Totton SC, et al. A systematic review and network meta-analysis of bacterial and viral vaccines, administered at or near arrival at the feedlot, for control of bovine respiratory disease in beef cattle. Anim Health Res Rev 2019;20 (2): 143-162.

31. Hilton WM. Management of Preconditioned Calves and Impacts of Preconditioning. Vet Clin North Am Food Anim Pract 2015;31 (2): 197-207.

32. Fulton RW, Cook BJ, Step DL, et al. Evaluation of health status of calves and the impact on feedlot performance: assessment of a retained ownership program for postweaning calves. Can J Vet Res 2002;66 (3): 173-180.

33. Richeson JT and Falkner TR. Bovine Respiratory Disease Vaccination: What Is the Effect of Timing? Vet Clin North Am Food Anim Pract 2020;36 (2): 473-485.

34. Chamorro MF and Palomares RA. Bovine Respiratory Disease Vaccination Against Viral Pathogens: Modified-Live Versus Inactivated Antigen Vaccines, Intranasal Versus Parenteral, What Is the Evidence? Vet Clin North Am Food Anim Pract 2020;36 (2): 461-472.

35. Perrett T, Johnson DL, Song J, et al. A retrospective analysis of feedlot morbidity and mortality outcomes in calves born to dams with known viral vaccination history. Can Vet J 2018;59 (7): 779-782.

36. Gillespie J, Kim S-A, and Paudel K. Why don't producers adopt best management practices? An analysis of the beef cattle industry. Agric Econ 2007;36 (1): 89-102.

Chapter 2: Technology adoption and management practices used in Canadian cow-calf herds

The adoption of technologies and use of beneficial management practices are important to increase production efficiency, reduce costs and ensure the sustainability of the Canadian cow-calf industry. Despite previous regional surveys, there is a need for comparable and comprehensive data describing the current use of technology in Canadian cow-calf herds. Survey data for the 2020 calendar year was collected from 131 cow-calf herds from across Canada. Data were summarized using descriptive statistics and logistic regression was used to determine associations between technology adoption and herd or producer attributes and productivity outcomes. Diverse herd circumstances and management goals impacted the uptake of various technologies across Canada; however, overall technology adoption has increased with a focus on growth and feed efficiency related tools. Expectedly, the use of technology was dependent on herd and producer characteristics.

Full citation: Lazurko, M.L., Campbell, J.R., Erickson N.E.N., Larson, K., Waldner, C.L. Technology adoption and record keeping practices in Canadian cow-calf herds. 2023.

Author contributions: Waldner designed the study. Waldner and Lazurko performed the statistical analyses. Lazurko gathered data and wrote the manuscript. Waldner, Campbell, Erickson, and Larson edited and provided feedback on the manuscript.

CHAPTER 2

Technology adoption and management practices used in Canadian cow-calf herds

Madelana M. Lazurko, John R. Campbell, Nathan E.N. Erickson, Kathy Larson, Cheryl L. Waldner

Department of Large Animal Clinical Sciences (Lazurko, Campbell, Erickson, Waldner), Western College of Veterinary Medicine, University of Saskatchewan, 52 Campus Drive, Saskatoon, Saskatchewan S7N 5B4; Saskatoon Saskatchewan, Canada; Department of Agricultural and Resource Economics (Larson), University of Saskatchewan, Saskatoon, SK, Canada

2.1 Abstract

Objective: Describe technology adoption and management practices used in Canadian cow-calf herds, assess associations between herd attributes, productivity outcomes and adoption; and identify opportunities for improvement.

Procedure: Analyze surveys from 131 Canadian cow-calf producers, recruited though a national surveillance program.

Results: Individual female records (80%) and feed testing (84%) were commonly reported as currently or occasionally used, followed by on-farm weigh scales (66%). Western herds were more likely to utilize feed testing and nutritionists, ionophores and growth promoting implants, while eastern herds more commonly used reproductive technologies. Large herds (>300 cows) were more likely to adopt technologies that aid in data capture (i.e., weigh scales, RFID scanners) and follow recommended practices (i.e., 63d or less breeding season, feed testing). Paper systems were the main record keeping format and production records were most commonly utilized for culling and replacement heifer selection.

Conclusions: Technology adoption has increased across the Canadian cow-calf industry. Producers are aware of and implementing technologies that increase production and economic efficiency. However, there is room to increase use of technologies that support more precise individual animal and herd data to make informed decisions.

Clinical relevance: Knowledge of gaps in the adoption of beneficial technologies can direct extension priorities and future research and help to customize messaging to the regional needs of cow-calf producers.

2.2 Introduction

Canadian cow-calf producers are facing increased pressure to adopt management practices and technologies to increase the economic viability, environmental sustainability, and public perception of beef production. One goal of the Canadian Beef Research and Technology Transfer Strategy is to "Support the ongoing surveillance of management practices and animal health and productivity information at the cow-calf and feedlot levels across Canada" (1). Similarly, the importance of technology adoption in the pursuit of improved beef production efficiency is outlined in Canada's National Beef Strategy (2). Canadian beef producers have little control over market prices and therefore, to remain viable, must continually search for ways to improve and increase the efficiency of productivity in their herds. Adoption of recommended practices and technologies can assist producers in meeting their productivity and financial goals.

Recently, there have been targeted investigations and analyses of management practices and technology adoption using Statistics Canada data (3) and independent surveys funded by research and industry associations (4-7). One of the major limitations to understanding current technology and management practices was the lack of uniform data from across Canada beyond that provided by Statistics Canada. Previous herd management surveys investigated management practices and productivity outcomes within specific regions or provinces (8-11). Similarly, previous research that investigated associations between herd management practices and herd productivity outcomes were regionalized and not representative of the whole country (5-7, 12-15). Attempts have been made to merge regional production surveys (4), but lack of uniform data made interpretation difficult.

Manglai et al. reported in 2016 that while over 90% of surveyed Canadian cow-calf producers set production goals, only 68% set financial goals (7). A key component of farm business management is setting goals to guide strategy, resource allocation and decision-making (16). The recommended way for producers to measure progress towards goals and identify areas for improvement is to maintain productivity and financial records.

Data and analysis are also needed to make high-involvement decisions (17). High-involvement decisions are infrequent, costly and have long-lasting impacts (i.e. heifer replacement selection, cow culling) and should be made with data for increased accuracy.

The objective of this study was to describe technology adoption, management and record keeping practices in Canadian cow-calf herds, assess associations between adoption and productivity outcomes, and identify opportunities for improvement.

2.3 Materials and Methods

This study was approved by the University of Saskatchewan's Behavioural Research Ethics Board (Beh-REB#309).

2.3.1 Survey design and content

A paper-based survey was developed based on questions previously used and tested (7). The updated survey was then implemented to assess technology adoption and record keeping practices between January 1st and December 31, 2020, in Canadian cow-calf herds. Part A of the survey asked about technology adoption and record keeping practices used by cow-calf producers, while Part B of the survey asked about herd vaccination protocols (data reported elsewhere).

The survey collected information regarding herd management decisions, technologies used on-farm and record keeping practices. These questions were presented as fill in the blanks and check boxes. Producers were asked to identify their operations based on types of beef production activities, classes and number of cattle maintained, commercial vs purebred/seedstock, retention of weaned calves, and purchase and retention of replacement heifers. Producers were then asked about their use of listed technologies and record keeping practices including calving/weaning, feeding/pasture use, breeding management, herd and animal health, death loss and culling records. A copy of the survey is available upon request to the corresponding author.

Productivity outcomes including calf death loss from 24 hours to weaning, calf treatment for scours and pneumonia, and proportion of nonpregnant females, were collected for the 2020 calendar year using a tool adapted from a productivity survey previously tested with Canadian cow-calf producers (18).

2.3.2 Participant recruitment and survey distribution

Participants in the Canadian Cow-Calf Surveillance Network (C3SN), a national cattle health and productivity surveillance network established in 2018, were eligible to receive this survey. Producers included in C3SN were to have a breeding herd size of ≥ 40 breeding animals, maintain calving records, routinely conduct pregnancy checks, and have access to internet for email communications. Producers were recruited through veterinarians, provincial producer groups and social media. In July 2021, technology adoption and record keeping surveys were mailed to 162 participating herds across Canada.

2.3.3 Data management and statistical analysis

Responses were entered into a commercial spreadsheet program and checked for accuracy. Data from the technology adoption survey was merged with producer attributes and production records from previous surveys of the same cohort (Microsoft Access; Microsoft, St. Louis, Missouri, USA).

Unconditional logistic regression was used to assess potential associations between herd and producer attributes (risk factors listed in Table 2.6 and 2.7), and technology adoption (currently used technologies listed in Table 2.1) as the outcome (StataCorp LP, College Station, Texas). Associations between herd/producer attributes and record keeping practice adoption were also assessed. Record keeping practices included maintenance of herd treatment records, individual animal treatment records, death loss records and culling records; as well as record storage format (electronic vs paper), person responsible for analysis of production records (consultant vs self/family member) and financial records (accountant vs self/family member), producers who set production or financial goals (yes vs no), and frequency of post mortem examinations (as often as possible/when death is unexplained vs rarely or never). P-values based on Wald tests were reported to assess the significance of categorical variables with more than two categories.

Associations between technology/record keeping practices previously listed and productivity outcomes listed in Table 2.9 were investigated using generalized estimating equations to account for clustering of outcomes within herd, a logit link function, binomial distribution, and exchangeable covariance structure (SAS for Windows ver 9.4, SAS Institute, Cary NC). Counts of the productivity outcomes of interest (calf mortality before and after 24 hours of age, calf treatment for scours or pneumonia, and breeding females not pregnant when tested) for each herd were included as the numerator and the total numbers of animals at risk in each herd as the denominator. Resulting risk factors from unconditional analyses with P-values <0.20 were considered in developing a multivariable analysis and final model. Where more than 1 factor was potentially associated, a causal diagram was considered before model building. Where risk factors were highly correlated or intervening variables were identified, variables were examined in independent competing models with the model with the lowest QIC considered to have the best fit. Associations were reported as odds ratios (OR) with 95% confidence intervals (95%CI); $p<0.05$ was considered statistically significant.

2.4 Results

2.4.1 Herd Demographics

The response rate for this survey was 81% (131/162). Responding producers were located in all four western prairie provinces (British Columbia (6), Alberta (40), Saskatchewan (27), Manitoba (18)) as well as 4 eastern provinces (Ontario (20), Quebec (16), Nova Scotia (2) and New Brunswick (2)). A larger percentage of respondents were from western Canada (69%, 91/131) than eastern Canada (31%, 40/131). Many producers reported multi-sector operations, which included backgrounding (55%), stocker (25%) or feedlot (15%) operations in addition to their cow-calf operation. Four percent (5/131) of producers maintained solely purebred cow-calf herds, 61% (80/131) maintained solely commercial herds, and 35% (46/131) maintained both commercial and purebred cattle in their cow-calf herd.

The average breeding cow herd size was 193 cows (standard deviation [SD] 178), with smaller herds in eastern provinces (average 76, SD 43) and larger herds in the western provinces (average 244, SD 189). The average number of bred heifers per herd was 34 (SD 37).

For most herds, calving started between January and April (January 24%, February 14%, March 25%, April 24%) and calving locations included corral or dry lots (40%), small pastures or paddocks (37%), barns or covered sheds (27%), and large pastures (16%). Producers could identify more than one month if they had two calving seasons.

2.4.2 Technology adoption and management practices

Twenty-three technologies and management practices currently used, occasionally used, previously used, and never used by Canadian cow-calf producers were reported for the 2020 calendar year (Table 1). Practices adopted and currently used by over half of survey respondents included maintenance of individual female production records (69%), feed and/or forage quality testing (61%), and use of an on-farm scale for weighing animals (56%). Technologies reported as never adopted by over 75% of herds included use of telemetry devices (95%), drones (86%), sexed semen (85%), and remote water monitoring systems (78%). Genetic and reproductive technologies including parentage testing (21%), genetic testing (18%), artificial insemination (AI) (cows: 26%, heifers: 28%), embryo transfer (12%), estrus synchronization (15%) and a defined breeding season of ≤63 days (45%) were currently used in less than half of the herds. Growth promoting implants were currently administered to suckling calves (31%) more often than to weaned calves (18%). While feed testing was currently utilized by 61% of producers, water testing was utilized by only 18% of producers.

2.4.3 Record keeping and ranch management decisions

When asked why producers chose to utilize production records, the top three most common reasons were: culling decisions (84%), replacement heifer selection (82%) and sire selection (50%) (Table 2.2). Records were most likely to be analyzed by the producer (90%) or a family member (23%).

The most common method for record keeping was written paper records (90%) and electronic spreadsheets (47%), but most (70%) producers did maintain records both on paper and in a computer spreadsheet or program. One producer did not keep any records.

Between 21-24% of producers relied solely on themselves to make decisions including overall ranch, financial, production and marketing decisions (Table 2.3). For those producers who discussed decisions with others, the most common resource for overall ranch decisions were herd veterinarians (49%) followed by peer group/networks (41%). Sixty-four percent of producers discussed financial decisions with their accountant (Table 2.3). Production decisions were commonly discussed with peer groups (45%) and veterinarians (44%) while marketing decisions were almost solely discussed with peers (56%) (Table 2.3).

Herd and operation financial records were commonly used for tax preparation (96%, 126/131), followed by capital investment analysis (52%, 68/131) and cash flow planning (50%, 66/131). To assess overall financial herd performance, the most common metrics used were net cash income (61%, 80/131), and accrual net farm income (42%, 55/131).

Setting production goals (79%, 104/131) was more common than setting financial goals (64%, 84/131). Most producers reflected on past financial (91%, 119/131) and production performance (87%, 114/131) to identify areas for improvement.

2.4.4 Production records

Reported data were similar for most herds across feeding management, breeding management, calving and weaning, and animal health records (Table 2.4). Pasture use or grazing management (73%) as well as mineral purchase and use (69%) and forage production (60%) were most likely to be included in feeding and pasture management records (Table 2.4). Winter feeding details were tracked by less than half of producers but were more common among western than eastern producers (48% vs 33%) (Appendix Table A2). Nearly all breeding records included bull turnout and pull dates (97%) (Table 2.4), but a larger proportion of producers from western provinces recorded bull testing records (92%, 84/91) compared to producers from eastern provinces (38%, 15/40) (Appendix Table A2).

Almost all calving records included calf sex (98%), birth date (97%), calving assistance (96%) and calf and dam identification (93%). The least commonly reported calving and weaning records were calf birth weights (55%) and individual calf weaning weights (45%) (Table 2.4). A larger proportion of producers from eastern provinces record birth weight (75%, 30/40) and weaning weight (55%, 22/40) compared to western producers (46%, 42/91; 41%, 37/91) (Refer to Appendix Table A2). Data commonly recorded in animal health records included vaccine use (91%), death loss (86%), antibiotic use (85%) and culling decisions (84%) (Table 2.4).

Specific data included in herd and individual animal treatment records also varied to a limited extent across operations (Table 2.4). Eighty-two percent (108/131) of herds maintained both herd level and individual animal treatment records, 3% (4/131) maintained only herd level treatment records and 9% (12/131) maintained only individual animal treatment records. Both herd level and individual animal treatment records commonly consisted of treatment date (83%, 92%), product administered (80%, 88%), and identity of group treated/animal identification (71%, 92%).

Both culling and mortality records commonly consisted of animal identification, date of cull/death, reason for culling/death, and animal type (Table 2.5). Culling and mortality records were not maintained by 10% and 9% of producers, respectively. Only about 1 in 5 producers (18%) had veterinarians' complete post-mortem examinations "as often as possible". Roughly half of the producers had veterinarians perform post-mortem examinations "very rarely" (43%), while 8% never had animals examined post-mortem (Table 2.5).

2.4.5 Herd and producer characteristics associated with technology adoption

Western producers were more likely to adopt the use of ionophores in breeding cows and growth promoting implants in calves (Table 6). Western producers were also more likely to adopt practices such as feed testing (73% vs 35%) and use of a nutritionist (46% vs 15%). Participating herds from eastern Canada were more likely to use artificial insemination (AI) in their cows (43% vs 19%) than herds from the west (refer to Appendix Table A1).

Producers with post secondary education were more likely to utilize feed testing, nutritionists, and on-farm scales for weighing animals compared to those with a high school education (Table 2.6). Producers under the age of 40 were less likely to use ionophores in breeding cows than older producers (Table 2.6).

Commercial herds with no sales of purebred animals were about five times less likely to have an on-farm scale for weighing animals than herds with at least some purebred sales (Table 2.6). Commercial herds were also less likely to adopt breeding and genetic technologies including estrus synchronization, AI, embryo transfer, and genetic/parentage testing than mixed herds with both commercial and purebred females (Table 2.6). Commercial herds were more likely to use growth promoting ear implants in suckling calves than herds with at least some purebred sales (Table 2.6).

Operations that consisted of solely a cow-calf herd were less likely to adopt technologies than operations that had other stages of beef production (i.e., backgrounding, feedlot finishing), such as a defined breeding season, growth promoting implants in weaned calves, and an on-farm weigh scale (Table 2.6). Consistent with this observation, producers that retained >50% of their 2020 calf crop for at least two months post-weaning were more likely to report the use of these practices and technologies compared to producers that did not retain >50% of calves (Table 2.6).

In addition, producers that retained calves were more likely to report estrus synchronization in cows and the use of an RFID tag scanner. Producers that did not retain a substantial portion of their calves were more likely to use remote monitoring/camera systems (Table 2.6).

Breeding cow herd size was associated with the adoption of some technologies (Table 2.7). Operations with large cow herds (>300 head) were more likely to utilize a defined breeding season, RFID tag scanners, nutritionists, feed testing, and remote water monitoring systems compared to small (<100 head) and medium sized cow herds (100-300 head) (Table 2.7). Operations with medium and large sized cow herds were more likely to utilize growth promoting ear implants in suckling and weaned calves compared to operations with small cow herds (Table 2.7). Finally, medium sized cow herds were less likely to utilize an on-farm scale compared to large herds (Table 2.7).

Calving location (pasture, corral, or barn) was associated with the adoption of growth promoting implants, AI and use of cameras or remote monitoring technologies (Table 2.7). Herds that used a barn for calving as opposed to a pasture were more likely to use AI in cows and heifers. Herds that used barns or corrals were more likely to report remote monitoring technologies such as cameras for calving than herds that calved on pasture. Herds that calved in barns were less likely to use growth promoting ear implants than herds that calved on pasture (Table 2.7). This is likely explained by the previous finding that purebred herds were less likely to use implants. These producers, specifically in western Canada would likely calve in barns.

2.4.6 Record keeping practices and associated herd and producer attributes

Producers from western provinces, those with commercial herds, and those calving in corrals or dry lots were less likely to have professional accountants analyze their financial records than herds in the eastern provinces, herds that had some purebred cattle, or herds calving in barns (Table 2.8). Western producers were also less likely to have consultants assist in production record analysis, opting to do it themselves or have a family member analyze the data (Table 2.8). Producers with commercial herds were less likely to maintain individual female production records and request routine post-mortem examinations of deadstock compared to herds with some purebred cattle (Table 2.8). Finally, producers with post secondary education were more likely to store production records electronically instead of on paper compared to those with a high school education (Table 2.8).

2.4.7 Cow-calf herd productivity outcomes and technology or record keeping adoption

Calf productivity outcomes including calf mortality (before and after 24hrs of age), treatment for pneumonia and calf scours, and risk of pregnancy failure were investigated for any associations with technology adoption after accounting for herd size or month of calving as potential confounders (Table 2.9). Producers that used AI in cows had a higher likelihood of calf mortality after 24 hours post-calving, while producers that tested water sources had lower odds of calf mortality before 24 hours of age. Producers that maintained herd treatment records and set financial goals were less likely to report treating calves for pneumonia than those that did not. Producers that utilized feed testing, nutritionists and remote water monitoring systems were less likely to report treating for calf scours than those that did not (Table 2.9). The use of a defined breeding season of up to 63 days was associated with increased odds that a cow would not be pregnant when tested, while the use of remote monitoring systems or cameras was associated with lower odds of nonpregnancy (Table 2.9).

2.5 Discussion

Adoption of technologies that facilitate increased production efficiency and animal health, and economic sustainability is essential for the sustainability of beef production. Though this cohort of beef producers likely represents a progressive subset of ranchers rather than the general Canadian population, the Diffusion of Innovations model tells us that identifying the actions and motivations of the "early adopters" and "early majority" is critical when identifying willingness to adopt and trends in technology use in the industry as a whole (19) . If the most innovative producers (such as those in this cohort) are not willing to adopt certain practices, uptake of the technology is not likely to reach the critical mass necessary for mass uptake and sustained use, and further investigation is needed to identify barriers for adoption (20-22). Technologies used by cow-calf producers in 2020 varied across Canada; however, the most frequently adopted practices were maintenance of individual female production records, feed testing, and animal weigh scales. Though maintenance of some components of individual female production records was common, the depth and data included in these records varied between herds. While over half the producers adopted these three technologies, there is opportunity for increased adoption of these and other technologies.

The adoption of technologies that facilitate animal productivity and precision feeding were more common than the adoption of breeding and genetic technologies. Precision feeding involves the maximization of available feedstuffs to meet the animals nutritional requirements with the least waste and best environmental outcome (23). Feed and water testing provide critical data to maintain health and reproductive efficiency and prevent nutrient toxicity. Testing feed sources can help producers manage feed resources more efficiently and effectively, especially in times of feed scarcity. Feed is often the largest cost for cow-calf producers (24); a feed quality test enables producers to develop low-cost rations and reduce feed waste. The proportion of producers in western Canada who utilized feed testing was slightly higher than previous reports with 73% (refer to Appendix Table A1) currently feed testing, compared to the previous high of 60% in western Canadian herds (8). Also, compared to previous western Canadian reports, the use of water testing by western producers appears to be increased (5% vs 20%) (8). Reports from eastern Canada described those who had water tested at least once in the last five years (30% Ontario, 41% northern Ontario, 17% northern Quebec) (9, 10). Water testing is becoming increasingly important, especially in the prairie regions as drought conditions can cause increased salinity in dugouts and ponds used for cattle watering, which can result in decreased animal performance and death (25).

Compared to previous surveys from different regions across Canada, the use of AI, embryo transfer and estrus synchronization remained close to previous estimates (4). However, the use of a defined breeding season of ≤63 days has approximately doubled (45%) compared to a 2017 survey of western Canadian producers (20%) (8), but was very similar to studies of western Canadian herds from 2001 (48%) and 2022 (40%) (14, 26). A defined calving period of 60 days has shown to produce a higher net return ($/head) when compared to a 90 day calving period (27). In both large and small herds, reducing the calving period from 120 days to 60 days increased net return per head (28).

New and emerging technologies including drones, cameras and remote monitoring systems give producers the ability to monitor cattle on an individual animal basis and increase traceability (29). While nearly 50% of producers used cameras, there will likely be increasing applications of tools such as drones for monitoring fence lines, cattle morbidity and location on pasture (30, 31). Cameras were more likely to be used in operations that calved in barns and corrals, which makes intuitive sense as electricity is likely more accessible, and the cameras will likely have good coverage area compared to extensive management systems. In addition, there is an expected greater need for monitoring in herds calving early in the year in the cold and particularly with purebred producers due to the value of individual animals and importance of preventing frost bite damage to ears.

Technology adoption varied across the country. Producers from western provinces were more likely to adopt practices focussed on increasing average daily gain and feeding precision, while eastern producers were more likely to adopt breeding technologies including AI. This regional difference in AI use is comparable to that reported previously (8, 9, 11). These differences are likely attributed to smaller herd sizes and increased comfort and familiarity with practices common in eastern Canada due to the thriving dairy industry, where the use of AI is very common.

Herd size was a large factor in whether the producer utilized different technologies. Large herds were likely more prone to adopt specific technologies compared to mid-sized or smaller herds. This is likely explained by economies of scale, as large operations have an economic advantage over smaller operations as they are able to spread the fixed costs of technologies across more animals which makes the technologies more affordable.

Commercial operations were less likely to adopt breeding and genetic technologies than mixed or purebred herds but were more likely to use growth promoting implants in suckling calves. Use of growth promoting implants in calves was higher than in previous studies when producers were last surveyed (4). Commercial producers were primarily focussed on calf growth prior to weaning, whereas genetic improvement, including growth, was critical for purebred producers. Herds that calved in barns were also more likely to use AI compared to those that calved on pastures. This is expected as those with some or all purebred cattle were more likely to use AI, and purebred herds often calve in barns in colder months of the year in Canada. Similarly, herds that retained calves post weaning were more likely to use a defined breeding season and estrus synchronization in their cows, both practices can reduce calving season duration which leads to greater uniformity in calves at weaning. Purebred breeders are also likely to retain more calves after weaning for bull and replacement female sales than many commercial producers. Altogether these data show differences in adoption of technology between primarily commercial and purebred herds. Segmentation and lack of vertical integration in the beef production industry might be a driving force for specific operator's choice in technology adoption (32). Different technologies will benefit certain segments of the industry and maintain economic sustainability whereas others may not; technology adoption could be, in part, commodity specific (32).

Producers with a post secondary education were more likely to adopt practices that increase production efficiency and reduce economic loss, such as feed testing and weighing cattle. Producers under the age of 40 were less likely to use ionophores in breeding cows. This may be indicative of the small profit margins in the cow-calf industry in 2020 caused by low cattle prices due to the COVID19 pandemic (33). Economic pressures may have forced producers to cut input costs such as feeding ionophores to cows to maintain budgets.

Maintenance of individual female production records was the most utilized practice of all technologies and record keeping options with calving records being the most commonly maintained individual animal record. It is important to note that while producers did collect data on their individual cows, less than half of producers collected individual calf weaning weights. Weaning weights are a valuable number for directly analyzing cow efficiency and informing culling and breeding decisions (34). The findings from the present study were similar to a 2017 survey of western Canadian herds that also found producers reported calf birth date, calf ID, and difficulty calving commonly in calving records (13).

Also similar to the 2017 study, most herds in the current survey recorded production records on paper, with less than half using electronic spreadsheets alone or in combination with paper records (13). Murray et al. (2016) reported most Alberta producers recorded data on paper; however, only one in four recorded data on paper and entered into an electronic spreadsheet, and 3% entered data directly into an electronic spreadsheet (6). Previous regional surveys from eastern Canada found that between 88 and 99% of producers used paper for their primary production records (9-11). Jelinski et al. (2019) reported in an analysis of census data that producers in the west were more likely to use electronics including smartphones, tablets and computers than eastern herds (3).

Producers with post secondary educations were more likely to store production records electronically compared to those with no post secondary education. Unlike a survey of US cow-calf producers, no associations were found between herds with purebred cattle or large herds and electronic storage of records (35). While the requirement for participating herds to have email access could have caused selection bias regarding use of electronic record keeping systems, there was still room for improvement in uptake of this practice as electronic data management allows for increased flexibility and capacity to analyse herd and individual animal data. As demand for electronic software increases in the industry, propriety software programs, for both handheld devices and PCs are emerging from both private companies and breed associations (36).

The most common reason producers chose to utilize their available production records was to assist in culling decisions and replacement heifer selection. However, few herds used production records for evaluating economic outcomes. There is little previous literature assessing Canadian producer's economic decisions and management choices. A smaller percentage of producers set production goals in 2020 (79%) than western Canadian producers surveyed in

2013-2015 (92%), but the percentage that set financial goals (64%) was similar (68%) (7). Interestingly, while more producers set production goals than financial goals, a larger proportion of producers used past financial performance to identify areas for improvement than past production performance.

The most common reason to maintain financial records was for tax preparation. Western producers, and producers with commercial herds were less likely to use accountants to analyze financial records than eastern producers, and herds with some or all purebred cattle. The top three most common groups that producers discussed ranch decisions with were accountants, peer groups, and veterinarians. For those who did consult with a veterinarian, the depth of consultation is unknown and likely variable between herds. Manglai et al. (2016) reported that those who discussed production with veterinarians, paid consultants and other farmers or discussion groups had greater returns (7). Almost one in four producers did not consult with anyone on their beef production decisions.

Vaccine use along with death loss, antibiotic use, culling, individual animal health records and parasite control were all common data recorded in animal health records. Death loss, antibiotic use and culling were also reported, but slightly less often. Most producers maintained culling and death loss records, but producers "very rarely" (45%) had veterinarians conduct post-mortems on deceased animals. This was likely an economic decision rather than disinterest in the information gained from a post-mortem, as 35% of producers had post-mortems performed "routinely" when the death was unexplained, or the animal was of high value.

This study identified several associations between the adoption of herd health and productivity technologies and herd health outcomes. Though biologically unimportant, the associations between adoption of organizational and administrative technologies including maintenance of herd treatment records and setting financial goals and the reduced risk of calf treatment may showcase calf health outcomes that are achievable as the result of a more evidence based, organized, and intentional management style. Consistent with a previous study from western Canada, producers that reported using reproductive technologies on their breeding cattle in the spring, i.e. AI, also reported higher calf mortality from 24 hours to weaning; the association between the use of reproductive technologies that require cows and calves to be gathered together during breeding time have been shown in a number of studies to be associated with an increased risk of diseases, such as BRD in young calves. The associated stress and increased opportunity for transmission when calves are crowded together might explain this association (5, 37). Treatment for calf scours was reported less frequently in herds adopting practices including feed testing, use of a nutritionist and remote water monitoring systems. Nutrition during the dry period has a direct effect on colostrum quality which can impact calf health outcomes (38, 39). Similar to findings by Waldner et al. (2013), the risk of nonpregnancy in breeding females was higher for herds that used a defined breeding season of ≤63 days (14). This finding is expected as a reduced breeding season length results in increased selection pressure on fertility and may result in a higher proportion of females that do not get pregnant in the strict timeframe.

The results of this analysis suggest that Canadian cow-calf producers continue to increase their use of available technologies and strive for more efficient and sustainable beef production. Producers from different sectors and those with different types of cow-calf herds naturally have different production goals based on their primary source of income. The adoption of technologies that increase animal growth and feeding precision were more common than breeding and genetic technologies, but the most utilised practice was maintenance of individual female production records. For those technologies for which previous usage data was available, adoption either increased or remained static.

There are potential opportunities for increased adoption of novel technologies such as drones that increase efficiency of observing and managing cattle remotely, enabling greater precision and traceability, necessary for the sustainability of the industry. Further increasing the use of software programs for the collection and management of herd records would allow producers to better reflect on past performance and increase profitability in the future. A key data point for direct analysis of individual cow productivity is individual calf weaning weights. Increasing the number of producers who collect this data could help in culling and breeding selection for more profitable and productive cows. There are also opportunities to increase the use of feed testing and nutritionists to reduce feed wastage and increase growth and reproductive efficiency, particularly in eastern Canada. Finally, the results of this study emphasize the importance of recognizing the diversity within the beef industry when designing knowledge translation activities. Recommended best management practices will vary with the type and goals of the operation.

2.6 References

1. Beef Cattle Research Council (BCRC). Canadian Beef Research & Technology Transfer Strategy, 2021.

2. Canada's National Beef Strategy 2020-24. Canadian Cattle Association. Available from https://beefstrategy.com/pdf/2022/NBS%202020-24%20Updated%20Sept%2022%202022.pdf.

3. Jelinski M, Bergen R, Grant B, and Waldner C. Adoption of technology and management practices by Canadian cow-calf producers. Can Vet J 2019;60 (3): 287-293.

4. Davidson TM and Canfax Research Services. Beef Cattle Research Council (BCRC): Adoption Rates of Recommended Practices by Cow-Calf Operators in Canada, 2019.

5. Waldner CL, Wilhelm B, Windeyer MC, Parker S, and Campbell J. Improving beef calf health: frequency of disease syndromes, uptake of management practices following calving, and potential for antimicrobial use reduction in western Canadian herds. Transl Anim Sci 2022;6 (4): txac151.

6. Murray CF, Fick LJ, Pajor EA, Barkema HW, Jelinski MD, and Windeyer MC. Calf management practices and associations with herd-level morbidity and mortality on beef cow-calf operations. Animal 2015;10 (3): 468-477.

7. Manglai. Examining Record Keeping and Benchmarking Effects on the Production and Performance of Cow-calf Farms in Canada Saskatoon: University of Saskatchewan, 2016.

8. "Western Canadian Cow-Calf Survey II". WCCCSN. University of Saskatchewan. Available from http://westernbeef.org/pdfs/wcccs/WCdnSurveyII_FINAL.pdf.

9. Ontario Cow-Calf 2015/16 Production Survey (OCC). OCC: University of Guelph. 2018. Available from https://www.beefresearch.ca/files/pdf/Ontario%20Cow-Calf%20Summary%20Nov%2012%202018.pdf.

10. Lamothe S and North Haven Solutions. Northern beef study: Northern Ontario and Northern Quebec beef cow-calf production. 2018.

11. Maritime Beef Council. Atlantic Cow-Calf Production Survey Aggregate Results, 2018.

12. Micheels ET and Nolan JF. Examining the effects of absorptive capacity and social capital on the adoption of agricultural innovations: A Canadian Prairie case study. Agric Syst 2016;145: 127-138.

13. Pearson JM, Pajor EA, Caulkett NA, Levy M, Campbell JR, and Windeyer MC. Benchmarking calving management practices on western Canada cow-calf operations. Transl Anim Sci 2019;3 (4): 1446-1459.

14. Waldner CL and Garcia Guerra A. Cow attributes, herd management, and reproductive history events associated with the risk of nonpregnancy in cow-calf herds in Western Canada. Theriogenology 2013;79 (7): 1083-1094.

15. Waldner C. Cow attributes, herd management, and reproductive history events associated with abortion in cow-calf herds from Western Canada. Theriogenology 2014;81 (6): 840-848.

16. Kay R, Edwards W, and Duffy P. Farm Management Ninth Edition. New York, NY: McGraw-Hill Education, 2020.

17. Bright D, Cortes A, Hartmann E, et al. Principles of Management. *OpenStax*, 2019.

18. Waldner CL, Parker S, and Campbell JR. Identifying performance benchmarks and determinants for reproductive performance and calf survival using a longitudinal field study of cow-calf herds in western Canada. PLoS One 2019;14 (7): e0219901.

19. Turner RJ. Diffusion of Innovations. J Minimally Invasive Gynecology 2007;14 (6): 776.

20. Diederen P, Van Meijl H, Wolters A, and Bijak K. Innovation adoption in agriculture : innovators, early adopters and laggards. Agric Econ 2003;67 (1): 29-50.

21. Hailu G. Reflections on technological progress in the agri-food industry: Past, present, and future. Can J Agric Econ 2023;71 (1): 119-141.

22. Makinde A, Islam MM, Wood KM, Conlin E, Williams M, and Scott SD. Investigating perceptions, adoption, and use of digital technologies in the Canadian beef industry. Comput Electron Agric 2022;198: 107095.

23. González LA, Kyriazakis I, and Tedeschi LO. Review: Precision nutrition of ruminants: approaches, challenges and potential gains. Animal 2018;12 (s2): s246-s261.

24. Multi-Year Economic, Productive & Financial Performance Of Alberta Cow/Calf Operations. AgriProfit$ Benchmarks for Alberta Cattlemen: Western Beef Development Center. Available from http://westernbeef.org/pdfs/economics/BeefTech/AB_2012-2016_Cost-of-Production-Benchmarks.pdf.

25. Water quality impacts on livestock. Agriculture and Agri-Food Canada: Government of Canada. Available from https://agriculture.canada.ca/en/agricultural-production/water/livestock-watering/water-quality-impacts-livestock.

26. Alberta Cow-Calf Audit 1997/98. Alberta Agriculture and Rural Development. Available from http://westernbeef.org/pdfs/economics/AB_CowCalf_Audit.pdf.

27. Boyer CNG, Andrew P. and Pohler KG. Improving Beef Cattle Profitability by Changing Calving Season Length. J Appl Farm Econ 2020;3 (1).

28. Boyer C, Burdine K, Rhinehart J, and Martinez C. Replacing late calving beef cows to shorten calving season. J Agric Resour Econ 2020;46 (2): 228-241.

29. Liu C, Jian Z, Xie M, and Cheng I. A Real-Time Mobile Application for Cattle Tracking using Video Captured from a Drone. International Symposium on Networks, Computers and Communications (ISNCC) Year: 1-6.

30. Hoagg J, Jackson J, Sama M, and Yang R. NRI: INT: Autonomous unmanned aerial robots for livestock health monitoring. 2020 National Robotics Initiative Principal Investigators Meeting Year

31. Using Drones to Monitor Fence Lines: AEN-159. Jackson J: University of Kentucky Agricultural Communications Service. Available from http://www2.ca.uky.edu/agcomm/pubs/AEN/AEN159/AEN159.pdf.

32. Terry SA, Basarab JA, Guan LL, McAllister TA, and Miglior F. Strategies to improve the efficiency of beef cattle production. Can J Anim Sci 2021;101 (1): 1-19.

33. Martinez CC, Maples JG, and Benavidez J. Beef Cattle Markets and COVID-19. Appl Econ Perspect Policy 2021;43 (1): 304-314.

34. Dinkel CA and Brown MA. An Evaluation of the Ratio of Calf Weight to Cow Weight as an Indicator of Cow Efficiency. J Anim Sci 1978;46 (3): 614-617.

35. Pruitt JR, Gillespie JM, Nehring RF, and Qushim B. Adoption of Technology, Management Practices, and Production Systems by U.S. Beef Cow-Calf Producers. J Agric Appl Econ 2012;44 (2): 203-222.

36. Data Management Pilot Project. Maritime Beef Council.: Maritime Beef Council. Available from https://maritimebeef.ca/resources/data-management-pilot-project-results/.

37. Woolums AR, Berghaus RD, Smith DR, et al. Case-control study to determine herd-level risk factors for bovine respiratory disease in nursing beef calves on cow-calf operations. J Am Vet Med Assoc 2018;252 (8): 989-994.

38. Pecka-Kiełb E, Zachwieja A, Wojtas E, and Zawadzki W. Influence of nutrition on the quality of colostrum and milk of ruminants. Mljekarstvo 2018;68 (3): 169-181.

39. Waldner CL and Rosengren LB. Factors associated with serum immunoglobulin levels in beef calves from Alberta and Saskatchewan and association between passive transfer and health outcomes. Can Vet J 2009;50 (3): 275-281.

2.7 Tables

Table 2.1 Technologies and practices adopted by Canadian cow-calf producers for use in their herd in 2020. Reported as proportion (number) of herds (n=131).

Technology/Practice	Currently use	Occasionally use	Previously used	Never used
Individual female production records	0.69 (91)	0.11 (14)	0.06 (8)	0.13 (17)
Forage/feed quality testing	0.61 (80)	0.23 (30)	0.08 (10)	0.08 (10)
On farm scale for weighing animals	0.56 (73)	0.10 (13)	0.03 (4)	0.31 (40)
Defined breeding season of ≤ 63 days	0.45 (59)	0.18 (24)	0.07 (9)	0.31 (40)
Cameras/ remote monitoring technologies	0.41 (54)	0.03 (4)	0.02 (3)	0.53 (70)
RFID tag scanner	0.38 (50)	0.05 (7)	0.08 (11)	0.49 (64)
Use of nutritionist	0.37 (48)	0.31 (40)	0.08 (10)	0.25 (33)
Growth promoting ear implant: suckling calves	0.31 (41)	0.02 (2)	0.14 (18)	0.53 (70)
Artificial insemination (heifers)	0.28 (37)	0.10 (13)	0.24 (31)	0.37 (48)
Ionophores in breeding cows	0.27 (35)	0.09 (12)	0.16 (21)	0.46 (60)
Artificial insemination (cows)	0.26 (34)	0.11 (15)	0.18 (23)	0.45 (59)
Parentage testing	0.21 (28)	0.11 (14)	0.03 (4)	0.64 (84)
Growth promoting ear implant: weaned calves	0.18 (24)	0.04 (5)	0.12 (16)	0.65 (85)
Water testing	0.18 (23)	0.24 (31)	0.25 (33)	0.33 (43)
Genetic Testing	0.18 (23)	0.06 (8)	0.04 (5)	0.72 (94)
Ionophores in suckling calves	0.17 (22)	0.09 (12)	0.08 (11)	0.64 (84)
Heat/Estrus sync. (heifers)	0.15 (19)	0.15 (20)	0.30 (39)	0.40 (53)
Heat/Estrus sync. (cows)	0.15 (19)	0.11 (15)	0.20 (26)	0.53 (70)
Remote water monitoring system	0.16 (21)	0.04 (5)	0.02 (2)	0.78 (102)
Embryo transfer	0.12 (16)	0.03 (4)	0.10 (13)	0.73 (96)
Drones	0.08 (11)	0.03 (4)	0.02 (2)	0.86 (113)
Sexed semen	0.04 (5)	0.04 (5)	0.08 (10)	0.85 (111)
Other	0.02 (2)	0.01 (1)	0 (0)	0.31 (40)
Telemetry devices	0 (0)	0 (0)	0.03 (4)	0.95 (124)

Table 2.2 Canadian cow-calf producer's reasons for utilizing production records in 2020 (n=131).

Utilization reason	Proportion of herds (n)
Culling decisions	0.84 (110)
Replacement heifer selection	0.82 (108)
Sire selection	0.50 (66)
Calculate individual animal production indicators	0.44 (57)
Calculate herd level production indicators	0.34 (45)
Evaluate progress towards goals	0.31 (41)
Marketing	0.29 (38)
Reporting to VBP+	0.27 (36)
Reporting to breed association	0.21 (28)
Cost of production analysis for individual farm enterprises	0.13 (17)
Calculate break even costs	0.08 (10)
Other (*Answers: AgriStability, track animal numbers, accounting, traceability*)	0.03 (4)
Negotiating with lender(s)	0.02 (2)

Table 2.3 Influential people in the decision-making process in Canadian cow-calf herds reported as proportion (number) of producers.

Information source (n=131)	Overall ranch decisions	Financial decisions	Production decisions	Marketing decisions
Veterinarian	**0.49 (64)**	0.03 (4)	**0.44 (57)**	0.03 (4)
Peer group, network	0.41 (54)	0.15 (20)	**0.45 (59)**	**0.56 (73)**
No one	0.24 (31)	0.22 (29)	0.21 (28)	0.24 (31)
Accountant	0.28 (37)	**0.64 (84)**	0.05 (7)	0.10 (13)
Paid consultants	0.13 (17)	0.10 (13)	0.15 (20)	0.08 (11)
Ag Extension personnel	0.12 (16)	0.02 (3)	0.17 (22)	0.05 (7)

Table 2.4 Data included in production records of Canadian cow-calf producers. Reported as proportion (number) of herds.

	All herds (n=131)
Feeding management and pasture use records	
Pasture use/ grazing management	0.73 (96)
Mineral purchases and use	0.69 (90)
Forage production	0.60 (78)
Feed purchases	0.47 (61)
Winter feeding details	0.44 (57)
Breeding management records	
Bull turnout and pull dates	0.97 (127)
Pregnancy testing records	0.89 (117)
Bull testing records	0.76 (99)
Calving and weaning records	
Calf sex	0.98 (128)
Birth date	0.97 (127)
Calving assistance	0.96 (126)
Calf's ID linked to dam ID	0.93 (122)
Cow health problems at calving	0.86 (113)
Weaning date	0.72 (94)
Birth weight	0.55 (72)
Individual weaning weight	0.45 (59)
Animal health records	
Vaccines	0.91 (119)
Death loss	0.86 (113)
Antibiotics	0.85 (111)
Culling	0.84 (110)
Individual animal health records	0.82 (107)
Parasite control	0.81 (106)
Pain control/NSAIDS	0.73 (96)
Herd level treatment records	
Date of treatment	0.83 (109)
Name of product administered	0.80 (105)
Identity of group treated	0.71 (93)
Number of animals treated	0.60 (78)
Dosage	0.54 (71)
Diagnosis or treatment reason	0.49 (64)
Injection or administration location	0.46 (60)
Other *(Answers: withdrawal time, product lot #)*	0.11 (15)
Did not maintain herd level treatment records	0.15 (19)
Individual animal treatment records included:	
Date of treatment	0.92 (121)
Animal ID	0.92 (120)
Name of product administered	0.88 (115)
Diagnosis or treatment reason	0.80 (105)
Dosage	0.76 (99)
Injection or administration location	0.53 (69)
Other *(Answers: withdrawal time, animal weight, animal temperature, administration site/method, product lot #)*	0.11 (15)
Did not maintain individual animal treatment records	0.08 (11)

Table 2.5 Information recorded in Canadian cow-calf producer's death loss and culling records, and frequency of post-mortem examinations reported as proportion (number) of producers.

Culling records included	
Animal ID	0.84 (110)
Date	0.76 (100)
Reason for culling	0.73 (96)
Animal type	0.69 (91)
Did not maintain culling records	0.10 (13)
Other	0.01 (1)
Death loss records included	
Animal ID	0.86 (113)
Date	0.82 (107)
Reason for death	0.80 (105)
Animal type	0.72 (94)
Record of veterinary post-mortem examination	0.20 (26)
Record of diagnostic laboratory testing results	0.11 (14)
Did not maintain death loss records	0.09 (12)
Other	0.04 (5)
Frequency of post-mortem examinations performed by a veterinarian	
Very rarely	0.43 (56)
Routinely (when death is unexplained, or animal was high value)	0.35 (46)
As often as possible	0.18 (24)
Never	0.08 (10)

Table 2.6 Summary of unconditional associations between technology adoption and herd/producer characteristics in Canadian cow-calf herds (n=131)[†].

Producer/herd attribute Technology adopted (yes vs no)	Odds Ratio	Lower 95% CI	Upper 95% CI	P-value
Western herds vs Eastern herds				
Ionophores in breeding cows	6.69	1.91	23.4	<0.01
Growth promoting ear implant in suckling calves	6.17	2.02	18.8	<0.01
Growth promoting ear implant in weaned calves	6.06	1.35	27.2	0.02
Forage/feed quality testing	4.90	2.21	10.9	<0.01
Use of nutritionist	4.86	1.86	12.7	<0.01
Artificial insemination (cows)	0.31	0.14	0.71	0.01
Producer gained post secondary education vs high school education				
Forage/feed quality testing	3.78	1.40	10.2	0.01
Use of nutritionist	3.88	1.08	14.0	0.04
On farm scale for weighing animals	2.98	1.11	7.98	0.03
Producer < 40 years of age vs >40 years of age				
Ionophores in breeding cows	0.34	0.15	0.78	0.01
100% commercial operation vs commercial and purebred or purebred operation				
Growth promoting ear implant in suckling calves	3.11	1.33	7.26	0.01
On farm scale for weighing animals	0.27	0.12	0.57	<0.01
Heat/Estrus synchronization (cows)	0.05	0.01	0.23	<0.01
Heat/Estrus synchronization (heifers)	0.18	0.06	0.53	<0.01
Artificial insemination (AI) (cows)	0.04	0.01	0.12	<0.01
Artificial insemination (AI) (heifers)	0.10	0.04	0.25	<0.01
Embryo transfer	0.03	0.00	0.24	<0.01
Genetic Testing	0.02	0.00	0.13	<0.01
Parentage testing	0.01	0.00	0.09	<0.01
Cow-calf operation only vs diversified operation with other beef production sectors				
Defined breeding season (≤63 d)	0.44	0.20	0.93	0.03
Growth promoting ear implant in weaned calves	0.14	0.03	0.63	0.01
On farm scale for weighing animals	0.46	0.22	0.97	0.04
Retained >50% of 2020 calf crop for ≥2 months post weaning vs did not retain >50% of calf crop				
Cameras/ remote monitoring technologies	0.44	0.22	0.89	0.02
Defined breeding season (≤63 d)	2.73	1.34	5.58	0.01
Heat/Estrus synchronization (cows)	5.94	1.64	21.5	0.01
Growth promoting ear implant in weaned calves	4.33	1.51	12.5	0.01
On farm scale for weighing animals	2.59	1.28	5.27	0.01
RFID tag scanner	2.11	1.02	4.36	0.04

[†]Only significant association were reported

Table 2.7 Unconditional associations between herd size and calving location, and adoption of technology in Canadian cow-calf herds (n=131)††.

Producer/herd attribute Technology adopted (yes vs no)		Odds Ratio	Lower 95% CI	Upper 95% CI	P-value
Breeding cow herd Size	Herd size				
Defined breeding season (≤63 d)	<100	1.00	0.46	2.19	>0.99
	100-300	(Ref)			**0.01**†
	>300	4.83	1.67	13.9	**<0.01**
Growth promoting ear implant in suckling calves	<100	0.17	0.06	0.48	**<0.01**
	100-300	(Ref)			**<0.01**†
	>300	1.18	0.46	3.07	0.73
Growth promoting ear implant in weaned calves	<100	0.08	0.01	0.63	**0.02**
	100-300	(Ref)			**<0.01**†
	>300	2.58	0.93	7.15	0.07
On farm scale for weighing animals	<100	1.41	0.66	3.05	0.38
	100-300	(Ref)			**0.03**
	>300	4.34	1.43	13.15	**0.01**
RFID tag scanner	<100	1.09	0.48	2.50	0.83
	100-300	(Ref)			**0.01**†
	>300	5.67	2.00	16.0	**<0.01**
Use of nutritionist	<100	0.80	0.34	1.89	0.61
	100-300	(Ref)			**0.01**†
	>300	7.00	2.39	20.5	**<0.01**
Forage/feed quality testing	<100	0.59	0.27	1.27	0.18
	100-300	(Ref)			**0.01**†
	>300	7.33	1.58	34.1	**0.01**
Remote water monitoring system	<100	0.60	0.17	2.15	0.44
	100-300	(Ref)			**0.01**†
	>300	3.90	1.28	11.9	**0.02**
Calving location	Location				
Artificial insemination (heifers)	Pasture	(Ref)			**0.03**†
	Corral	1.91	0.68	5.34	0.22
	Barn	3.82	1.44	10.1	**0.01**
Artificial insemination (cows)	Pasture	(Ref)			**0.01**†
	Corral	1.38	0.45	4.21	0.58
	Barn	4.40	1.62	12.0	**<0.01**
Artificial insemination any females	Pasture	(Ref)			**0.01**†
	Corral	1.68	0.61	4.60	0.31
	Barn	4.20	1.62	10.9	**<0.01**
	Pasture	(Ref)			**<0.01**†
Cameras/ remote monitoring technologies	Corral	5.60	2.14	14.6	**<0.01**
	Barn	6.60	2.52	17.3	**<0.01**
Growth promoting ear implant in weaned calves	Pasture	(Ref)			**0.05**†
	Corral	0.69	0.29	1.64	0.40
	Barn	0.32	0.13	0.79	**0.01**

†P-value based on Wald's test for multicategory variables; ††Only significant associations were reported.

Table 2.8 Unconditional associations between record keeping practices and herd or producer characteristics (n=131)[††].

Herd/producer attributes (yes vs no) Record keeping practice adoption	Odds Ratio	Lower 95% CI	Upper 95% CI	P-value
Western herd vs Eastern herd				
▪ Financial records analyzed by accountant (vs. self or family member)	0.32	0.14	0.73	**0.01**
▪ Production records analyzed by consultant (vs. self or family member)	0.16	0.03	0.86	**0.03**
Producer has post secondary education vs high school education only				
▪ Production records stored electronically (vs. paper)	3.13	1.20	8.15	**0.02**
100% commercial cow-calf herd vs commercial and purebred of purebred herd				
▪ Financial records analyzed by accountant (vs. self or family member)	0.39	0.18	0.84	**0.02**
▪ Maintains individual female production records (yes vs no)	0.41	0.18	0.93	**0.03**
▪ Does post-mortems as often as possible when the death is unexplained (vs. rarely or never)	0.45	0.22	0.93	**0.03**
Calving location				
▪ Financial records analysed by accountant (vs. self or family member)				
▪ Pasture	2.58	0.77	8.71	0.13
▪ Corral or dry lot	(Ref)			**0.02**[†]
▪ Barn or covered shed	5.54	1.61	19.0	**0.01**

[†]P-value for based on Wald's test for multicategory variables; [††]Only significant associations were reported.

Table 2.9 Multivariable associations reported use of herd management practices and technologies and productivity outcomes after accounting for herd size and month of calving as appropriate (n=124)†.

Technology or management practice used (currently use vs did not use)	Odds Ratio	Lower 95% CI	Upper 95% CI	P-value
Calf mortality before 24hrs old				
▪ Financial records analyzed by accountant	0.77	0.60	0.97	**0.03**
▪ Cow herd size				
<100	0.50	0.35	0.72	**<0.01**
100-200	0.70	0.50	0.98	**0.04**
>300	(Ref)			
Calf mortality after 24hrs old				
▪ Tested water sources	0.47	0.29	0.75	**<0.01**
▪ Used artificial insemination in Cows	1.66	1.17	2.36	**<0.01**
▪ Cow herd size				
<100	1.38	0.74	2.56	0.31
100-300	(Ref)			
>300	1.62	1.00	2.60	**0.05**
Calves treated for pneumonia				
▪ Maintained herd treatment records	0.31	0.15	0.64	**<0.01**
▪ Set financial goals	0.41	0.21	0.81	**0.01**
▪ Calving month				
Jan	0.11	0.05	0.26	**<0.01**
Feb	0.22	0.11	0.45	**<0.01**
Mar	(Ref)			
Apr	0.36	0.17	0.76	**0.01**
May	0.75	0.41	1.39	0.36
Nov-Dec	0.13	0.05	0.29	**<0.01**
Calves treated for scours				
▪ Tested feed/forage	0.56	0.33	0.95	**0.03**
▪ Used nutritionist	0.55	0.33	0.89	**0.02**
▪ Used remote watering system	0.42	0.22	0.78	**0.01**
▪ Set finance goals	0.57	0.33	1.01	0.06
▪ Calving month				
Jan	0.75	0.38	1.49	0.42
Feb	3.85	1.49	10.00	**0.01**
Mar	(Ref)			
Apr	1.69	0.79	3.70	0.17
May	8.33	2.56	25.00	**<0.01**
Nov-Dec	0.21	0.06	0.70	**0.01**
Breeding females not pregnant when tested				
▪ Used remote monitoring system/camera	0.76	0.60	0.97	**0.03**
▪ Used defined breeding season (≤63 days)	1.43	1.16	1.75	**<0.01**
▪ Calving month				
Jan	1.18	0.86	1.61	**0.01**
Feb	0.97	0.71	1.32	0.18
Mar	(Ref)			
Apr	0.88	0.69	1.14	**0.03**
May	0.76	0.60	0.97	0.31
Nov-Dec	1.27	0.56	2.78	0.57

† Only significant results reported and analysis completed for producers providing both technology survey data and production records for this period

CHAPTER 3: VACCINE USE IN CANADIAN COW-CALF HERDS AND OPPORTUNITIES FOR IMPROVEMENT

Using survey data collected from the same cohort of herds as Chapter 2, this chapter aimed to describe vaccine use in these herds and identify associations between vaccine use and herd or production attributes and calf productivity outcomes. Vaccine use has increased across Canada over the past few decades. Recommended core vaccines are the common targets administered to cattle. Use of intranasal vaccines in neonatal calves has increased and nearly all suckling calves are provided at least one vaccine. To ensure product efficacy and adequate immune protection in calves entering feedlots, product label instructions must be closely followed. More research is needed regarding the benefits of vaccinating calves early in life and to identify recommendations for optimal vaccine type and timing in suckling calves.

Full citation: Lazurko, M.L., Campbell, J.R., Erickson N.E.N., Gow, S., Waldner, C.L. Vaccine use in Canadian cow-calf herds and opportunities for improvement. 2023.

Author contributions: Waldner designed the study. Waldner and Lazurko performed the statistical analyses. Lazurko gathered data and wrote the manuscript. Waldner, Erickson, Campbell, and Gow edited and provided feedback on the manuscript.

CHAPTER 3

Vaccine use in Canadian cow-calf herds and opportunities for improvement

Madelana M. Lazurko, Nathan E.N. Erickson, John R. Campbell, Sheryl P. Gow, Cheryl L. Waldner

Department of Large Animal Clinical Sciences (Lazurko, Campbell, Erickson, Waldner), Western College of Veterinary Medicine, University of Saskatchewan, 52 Campus Drive, Saskatoon, Saskatchewan S7N 5B4; Public Health Agency of Canada (Gow), Saskatoon Saskatchewan, Canada

3.1 Abstract

Objective: Describe vaccination protocols and factors associated with vaccine use in Canadian cow-calf herds and define associations between vaccine use and productivity outcomes.

Procedure: Surveys were collected from 131 cow-calf herds (40 eastern, 91 western), recruited through a national beef cattle surveillance program.

Results: 92% of cows and replacement heifers and 72% of bulls were vaccinated Bovine viral diarrhea virus (BVDV), Infectious bovine rhinotracheitis (IBR), Bovine respiratory syncytial virus (BRSV), and Parainfluenza virus type 3 (PI3), with at least half of cows and bulls vaccinated for clostridial pathogens and cows and heifers for viral calf scours. Clostridial vaccines were significantly more likely to be used in all classes of cattle in western Canada than in eastern Canada. While 92% of producers vaccinated suckling calves against IBR/BRSV/PI3, only 47% provided a second vaccine prior to weaning; 78% of calves were also vaccinated at least once for BVDV before weaning. Producers who vaccinated calves against IBR/BRSV/PI3 before 3 months of age provided a second dose prior to weaning more often than producers who administer the first IBR/BRSV/PI3 vaccine later.

Conclusions: Vaccine use has increased across Canada, particularly in calves before weaning. Relative to label recommendations for annual vaccination, clostridial vaccines were underutilized in cows and bulls and by producers in eastern Canada as compared to western Canada. Protocols including product choices, the timing and boosting of respiratory vaccines in nursing calves vary widely across herds. Use of intranasal vaccines in neonatal calves in western Canada is higher in calves less than two weeks old than what was reported in 2016.

Clinical relevance: Vaccine usage data can help inform priorities for veterinary and producer education. Respiratory vaccine protocols for nursing calves should explore administration prior

to high risk of disease associated with decreasing immunity from colostrum and aim for two vaccines prior to weaning for optimum protection against BRD both before and after weaning. The wide variation in current protocols for respiratory vaccines in nursing calves suggests a need for evidence informed protocols to optimize effectiveness.

3.2 Introduction

Vaccination of beef cattle has proven effective in stimulating immune response and reducing disease burden across a range of study designs (1-8) . However, other studies of vaccine use in cow-calf herds and at feedlot entry have shown more variable effectiveness (9-18). Adherence to evidence-based vaccine protocols can improve animal health and increase production efficiency through control and prevention of economically important diseases (2, 7).

Vaccinating against reproductive and clostridial diseases is commonly recommended by veterinary practitioners (19). The American Association of Bovine Practitioners (AABP) identified the following targets as core vaccines for all beef cattle: Infectious Bovine Rhinotracheitis (IBR), Bovine Viral Diarrhea Virus (BVDV), Parainfluenza3 Virus (PI3), Bovine Respiratory Syncytial Virus (BRSV), and clostridial diseases with the label for all licensed products either requiring or recommending annual revaccination (20). The AABP recommends modified live viral (MLV) vaccines for IBR and BVDV due to the increased efficacy compared to killed or inactivated vaccines (20).

Other vaccines should be recommended by veterinarians on an individual herd basis, based on specific risk factors and geographical location (20). A number of studies have documented causes of morbidity and reasons for antimicrobial use in cow calf herds. For example, a 2015/2016 survey of Ontario cow-calf producers and a 2017 survey of western Canadian cow-calf producers found that neonatal calf scours (13–52%) and pre-weaning calf respiratory disease (15–16%) were important causes of total pre-weaning mortality (21, 22). Respiratory disease is the most reported reason for antimicrobial use in both cow-calf herds and feedlots (23, 24). Commercial vaccines labeled to aid in the control of scours and respiratory disease are available and are commonly used in cow-calf herds (25), although the results for published field trials are variable for both calf scours and respiratory disease preweaning (10, 12).

Timing of vaccine administration must be considered for optimizing effectiveness particularly for control of respiratory disease. While vaccination before weaning has been shown to reduce treatment for respiratory disease relative to vaccination at or after weaning and again at feedlot arrival (26, 27), improved performance across the entire feeding period was not observed in these studies for calves vaccinated before weaning. The evidence supporting beneficial effects of administration of respiratory vaccines at feedlot arrival is even more limited with many studies showing no or negative associations with vaccination (26, 28-31). The lack of current economic incentive for cow-calf producers to fully vaccinate calves prior to sale to prevent respiratory disease in feedlots limits participation by cow-calf producers.

Literature regarding national adoption and use of vaccines across the Canadian cow-calf industry is scarce. However, recent industry reports using cow-calf producer survey data have demonstrated regional vaccine use within Canada. Western Canadian studies have previously described vaccination protocols for the following years: 2016/2017 (21), 2010 (5) and 2001/2002 (6). Eastern Canadian cow-calf producers have been surveyed regarding vaccine use in Atlantic Provinces (2017) (32), Ontario (2015/2016) (33, 34), and northern Quebec (2015) (34).

A previous western Canadian surveys found that cow-calf producers used at least one vaccine in cows, heifers, unweaned calves, weaned calves and bulls in 97%, 97%, 96%, 57% and 72% of herds, respectively (25). The most common vaccine targets for calves were clostridial diseases, and respiratory and reproductive vaccines were the most common vaccines for bulls, cows and replacement heifers (25). Producers from eastern Canada had previously reported vaccine use among cows, heifers, calves and bulls in Ontario of 70%, 72%, 88%, and 59% and in northern Quebec of 72%, 78%, 94% and 68%, respectively (33, 34). Similar data were not reported for Atlantic herds, but 73% of producers reported vaccinating cattle, and 45% vaccinated females prior to breeding (32).

The primary objective of this study was to describe vaccine adoption in cow-calf herds across Canada and provide a better understanding of the types of vaccines used and timing of administration. Results will be used to investigate regional differences and opportunities for improvement in vaccination uptake and adherence to recommended protocols. The secondary objective of this study was to examine factors associated with vaccine use and explore potential associations between vaccine use and herd productivity outcomes.

3.3 Materials and Methods

This study was approved by the University of Saskatchewan's Behavioural Research Ethics Board (Beh-REB#309).

3.3.1 Survey design and content

A paper-based survey was developed based on a tool tested and used in western Canadian herds in 2016 (25). The survey requested herd data from January 1, 2020, to December 31, 2020, and was split into two parts: Part A inquired about herd characteristics, management practices, and technology adoption (data reported elsewhere), and Part B asked about specific herd vaccination protocols. Producers described vaccine use by completing a series of open text tables for each production group: bulls, cows, replacement heifers, weaned calves, and suckling calves. Each table was split into rows, based on vaccine target (e.g., bulls: reproductive, clostridial, respiratory, foot rot, anthrax and other) with space to allow for multiple vaccines per target. Commercial vaccine names were recorded, and time of administration relative to other herd management activities was selected from a list (e.g., bulls: before breeding, after breeding, or other) along with an indicator of whether it was the first or subsequent administration of a vaccine. Producers were also asked to identify the top factors considered when deciding to vaccinate suckling calves and select herd vaccine protocols. A copy of the survey is available from the corresponding author on request.

To facilitate the survey completion producers were encouraged to consult their records, expense receipts and veterinarians, if needed, for details. They were further provided with a handbook listing and describing bovine vaccines, with associated color photographs of product packaging for vaccines currently approved for use in beef cattle in Canada as an aid to recall. The handbook was developed in consultation with practicing beef cattle veterinarians.

Herd attributes including calving, health and productivity data for the 2020 breeding to weaning season were collected in June and December of 2020 using a survey adapted from a productivity survey previously tested and proven with Canadian cow-calf producers (35). Data from this survey were extracted and integrated with the results from the vaccine use survey.

3.3.2 Participant recruitment and survey distribution

All cow-calf producers participating in the Canadian Cow-Calf Surveillance Network (C3SN), a national cattle health and productivity surveillance network established in 2018, were sent the survey. Eligibility requirements for C3SN included: a breeding herd size of ≥ 40 animals, maintenance of calving records, routine pregnancy testing, and access to email. Herds were recruited through veterinarians, provincial producer groups and social media (36). In July 2021, vaccination surveys were mailed to 162 participating herds across Canada.

3.3.3 Data management and statistical analysis

Responses were entered into a commercial spreadsheet program and checked for accuracy by having a second person review data entry and through logical checks. Vaccine trade names as reported by producers were linked to a list of vaccines licensed for use in Canadian cattle according to the Compendium of Veterinary Products (37) to determine each of the vaccine's target components. Additional product details were obtained, if necessary, directly from product packaging and labels. Data from the vaccine use survey were merged with producer attribute data and production records (Microsoft Access; Microsoft, St. Louis, Missouri, USA).

Factors potentially associated with vaccine use, including cow herd size (small: <100 animals, medium: 100-300 animals, large: >300 animals), producer age (<40 years), and producer education level (post-secondary vs. high school), were investigated in a series of unconditional (univariate) analysis using logistic regression (StataCorp LP, College Station, Texas).

Analysis of associations of interest between vaccine use and productivity data were investigated using generalized estimating equations to account for clustering of outcomes within herd, a logit link function, binomial distribution, and exchangeable covariance structure (SAS for Windows ver 9.4, SAS Institute, Cary NC). Counts of the outcomes of interest for each herd were included as the numerator and the total numbers of animals at risk in each herd as the denominator adjusting for cow herd size, calving month and geographical location as potential confounders based on a recent data from this region (35). Associations were reported as odds ratios (OR) with 95% confidence intervals; $P<0.05$ was considered statistically significant.

3.4 Results

3.4.1 Study Population

Herds enrolled from British Columbia (6), Alberta (40), Saskatchewan (27), and Manitoba (18) were identified as being from western Canada (69% (91/131)), whereas herds from Ontario (20), Quebec (16), Nova Scotia (2) and New Brunswick (2) were identified as being from eastern Canada (31% (40/131)). Herds were described as primarily commercial (60%, 79/131), primarily purebred/ seedstock (4%, 5/131), and mixed commercial/purebred (36%, 47/131).

The mean number of breeding cows per herd was 193 (median 130, 5th and 95th percentile 40, 527). The mean number of breeding cows per herd in western operations was 244 (median 190, 5th and 95th percentile 64, 644) and 76 (median 65, 5th and 95th percentile 33, 162) in eastern herds. On average, operations had 34 (median 20, 5th and 95th percentile 1, 105) bred heifers and producers purchased in 7 (median 0, 5th and 95th percentile 0, 30) replacement breeding females during the 2020 calendar year.

Twenty-two percent of herds (28/130) were managed by at least one person under the age of thirty and 47% (61/130) under forty. Thirty percent (38/128) of herd managers reported a university degree, 21% (27/128) a college diploma, 18% (23/128) a professional trade, 15% (19/128) a graduate degree, and 16% (21/128) a high school diploma. Denominators differed for producer characteristics as some producers declined to answer some questions.

Many operations were diversified with other beef production operations; 55% (72/131) reported backgrounding calves, 25% (33/131) maintained stockers or grassers, and 15% (13/131) operated a feedlot. Thirty-four percent (44/131) of operations were strictly cow-calf. More than half of the 2020 calf crop was retained for at least two months post weaning in 53% (69/131) of herds. Forty-five (31/69) percent of herds that retained calves had some seedstock. Calving start dates varied and included January (24%, 31/131), February (14%, 18/131), March (25%, 33/131) and April (24%, 31/131). Reported primary calving facilities included pastures (53%, 69/131), corrals or dry lots (40%, 53/131), and barns or covered sheds (27%, 36/131). Community pastures were used by 21% (27/131) herds.

3.4.2 Vaccine use in bulls, cows, and replacement heifers

Most producers vaccinated bulls (83%), cows (97%) and replacement heifers (95%) with at least one vaccine between January 1 and December 31, 2020 (Table 3.1). Cows and replacement heifers from 92% of herds were vaccinated for BVDV, IBR, BRSV and PI3, with at least half of herds also vaccinating both groups for viral calf scours (coronavirus, rotavirus) (Table 3.1). However, 8% of producers did not administer BVDV/IBR/BRSV/PI3 vaccines to breeding females and only 17% of producers provided a second scours vaccine to heifers (Table 3.1). The percent of herds that vaccinated bulls for BVDV, IBR, BRSV and PI3 was lower than for cows. Vaccines for other reproductive diseases were reported less frequently for breeding stock, with replacement heifers most vaccinated against *Leptospira* spp. (36%) and *Campylobacter fetus* (23%).

Two-thirds of producers vaccinated their replacement heifers against clostridial disease, while only half vaccinated their cows and bulls during the year (Table 3.1). Eight-way products were the most common clostridial vaccines reported for bulls, cows and replacement heifers. (Table 3.1). Footrot (*Fusobacterium*) vaccine was administered to bulls in 31% of herds; while only one herd vaccinated cows (Table 3.1).

Vaccination timing in bulls, cows and replacement heifers was dependant on vaccine type (Table 3.2). More than half of producers vaccinated cows and most vaccinated replacement heifers against viral pathogens prior to breeding using a MLV product (Table 3.2). Modified live viral vaccines were most often administered prior to breeding, and inactivated vaccines were slightly more commonly administered at pregnancy testing. Twenty of the 22 herds (91%) that administered a MLV IBR/BVDV vaccine to replacement heifers at pregnancy checking had previously administered two doses of a MLV IBR/BVDV vaccine, and the two other herds administered one prior MLV IBR/BVDV vaccine. Apart from anthrax vaccines (nonencapsulated live culture), all other bacterial vaccines administered to cows and replacement heifers were inactivated. *Campylobacter* and *Leptospira* vaccines were commonly administered prior to breeding (Table 3.2). Producers who sent cows to community pasture were more likely to administer a *Campylobacter* vaccine (41%, 11/27), than those who did not use community pasture (16%, 17/104) ($p<0.01$). Cows were vaccinated for *Clostridia* spp. prior to breeding (21%), at pregnancy checking (22%), or before calving (15%). Heifers were vaccinated for clostridial disease prior to breeding in a higher proportion of herds than cows (Table 3.2).

Bulls from most herds were vaccinated before breeding (Table 3.2). Modified live BVDV, IBR, BRSV, PI3 vaccines were used in bulls more commonly than inactivated products. Two producers administered a commercially available parenteral (SQ) vaccine containing avirulent live cultured *P. multocida* and *M. haemolytica* to their bulls.

3.4.3 Vaccine use in calves

All calves, nursing and weaned considered together, received at least one vaccination in 99% of herds and were administered at least a second dose of one type of vaccine in 82% of herds (Table 3.3). The most common vaccine targets were IBR, BRSV, PI3, BVDV, *Clostridia* spp. and *M. haemolytica* (Table 3.3). The vaccines most likely to be followed by a second administration of a vaccine to the same target in calves, either before, at or after weaning were IBR, BRSV, and PI3 (77%), BVDV, (61%), clostridial vaccines (46%), and *M. haemolytica* (28%) (Table 3.3). Modified-live vaccines were used almost exclusively in calves for viral respiratory targets. Calves were administered at least one IN IBR/BRSV/PI3 vaccine prior to weaning in 33% (43/131) of herds. Bacterial respiratory vaccines including *M. haemolytica*, *H. somni* and *P. multocida* were administered to calves in 62%, 43% and 19% of herds, respectively. Thirty-four percent of all calves received at least one dose of a clostridial vaccine containing tetanus (Table 3.3).

Suckling calves received at least one vaccine in 98% of herds and the most common targets were IBR, BRSV, and PI3 (92%) as well as *Clostridia* spp. (87%), BVDV (78%), and *M. haemolytica* (56%) (Table 3.3). Most suckling calves were vaccinated after two weeks of age; however, the most common vaccine antigens administered prior to 2 weeks of age were for IBR/BRSV/PI3 (21%, 27/131) (Table 3.4).

Sixty-six percent of producers (87/131) vaccinated calves at or after weaning, most commonly against IBR/BRSV/PI3, BVDV and *M. haemolytica* (Table 3.3). Producers who retained >50% of their calf crop for ≥2 months post weaning administered IBR/BRSV/PI3 vaccines to calves at or after weaning (67%, 46/69) more often than those who did not retain calves (48%, 30/62) ($P<0.05$).

Vaccination protocols for IBR/BRSV/PI3 and BVDV were assembled into flow charts based on timing of first dose administered (Figures 1-3). Twenty-one (27/131) percent of producers administered IBR/BRSV/PI3 vaccines to calves before 2 weeks of age (26 intranasal [IN], 1 subcutaneous [SQ]) (Figure 3.1). BVDV vaccines were not administered prior to 2 weeks of age. Sixty-seven percent (18/27) of herds that vaccinated against IBR/BRSV/PI3 before 2 weeks of age also received a second IBR/BRSV/PI3 dose prior to weaning. Of the 27 herds vaccinated against IBR/BRSV/PI3 prior to 2 weeks of age, 59% (16/27) vaccinated against BVDV and 19% (5/27) provided a second BVDV dose prior to weaning.

Fifty-one percent (67/131) of producers administered initial viral respiratory vaccines between 2 weeks and 3 months of age; 12 IN IBR/BRSV/PI3, 3 IN IBR/BRSV/PI3 with SQ BVDV, and 52 SQ IBR/BRSV/PI3/BVDV (Figure 3.2). Fifty-two percent (35/67) of herds that were administered IBR/BRSV/PI3 vaccines between 2 weeks and 3 months were also administered a second IBR/BRSV/PI3 vaccine prior to weaning. Most herds administered a BVDV vaccine (88%, 59/67) and 45% (30/67) administered a second BVDV vaccine dose prior to weaning.

There was no significant difference in whether a herd would receive a second dose of IBR/BRSV/PI3 vaccine (p=0.25) before weaning if the calves were vaccinated for IBR/BRSV/PI3 for the first time between birth and 2 weeks or 2 weeks and 3 months. However, herds where calves were vaccinated with IBR/BRSV/PI3 vaccine before 2 weeks of age were less likely (p=0.04) than those vaccinated from 2 weeks to 3 months to administer a second BVDV vaccine dose.

Twenty percent (26/131) of calves were administered initial SQ IBR/BRSV/PI3 and BVDV vaccines between 3 months and weaning (Figure 3.3). Of those, 23% (6/26) were administered a second SQ IBR/BRSV/PI3 and BVDV vaccine, and 8% (2/26) were administered a second SQ IBR/BRSV/PI3 vaccine prior to weaning. Calves were more likely to receive a second dose of IBR/BRSV/PI3 vaccine (p=0.03), but not BVDV vaccine (p=0.47), before weaning if the calves were vaccinated for IBR/BRSV/PI3 for the first time between birth and 3 months than after 3 months.

Bacterial vaccines including *Clostridia* spp., *M. haemolytica, P. multocida,* and *H. somni* were typically administered to suckling calves after 2 weeks of age (Table 3.4). Few producers administered a second *M. haemolytica* (27%) or *Clostridia* spp. (26%) vaccine dose prior to weaning (Table 3.3).

Seventy percent (92/131) of producers vaccinated calves against clostridial disease prior to 3 months of age, but only one herd was administered a booster in that period. Twenty-five percent (33/131) administered a second clostridial vaccine between 3 months and weaning. Eighty-seven percent (114/131) of producers vaccinated calves against *Clostridia* spp. between birth and weaning, but only 26% (34/131) of producers administered a second clostridial vaccine before weaning. Eight-way vaccines with (21%, 28/131) and without (27%, 35/131) tetanus were the most common choices in suckling calves. Suckling calves were administered at least one vaccine containing *Cl. tetani* in 34% of herds (Table 3.3). Seven-way clostridial vaccines were the most common choice for weaned calves (Table 3.3).

Forty-seven percent of producers (61/131) administered vaccines containing *M. haemolytica* (15%, 20/131 with *P. multocida*), prior to 3 months of age, and four producers also administered a second *M. haemolytica* dose prior to 3 months. Thirty-five percent (46/131) vaccinated against *M. haemolytica* (7%, 9/131 with *P. multocida*) between 3 months of age and weaning. Of those 46 producers, one administered a second dose to calves again prior to weaning, 7 boosted at weaning, and 8 boosted after weaning. Intranasal *M. haemolytica* and *P. multocida* vaccines were administered in 10% (13/131) of herds, and one herd provided 2 doses of an IN *M. haemolytica* and *P. multocida* vaccine prior to weaning. All 9 herds that vaccinated against *M. haemolytica* and *P. multocida* between birth and 2 weeks used an intranasal vaccine.

3.4.4 Factors associated with vaccine use

Significant unconditional odds ratios were reported from logistic regression where cow herd size, retaining >50% of calves for ≥ 2 months after weaning and reporting only commercial vs some purebred cattle were associated with vaccine use (Table 3.5). Large herds were more likely to vaccinate cows and heifers against clostridial disease, weaned calves against *M. haemolytica* and clostridial disease, and suckling calves against *H. somni* compared to small herds. Medium sized herds were also more likely to vaccinate heifers and suckling calves against clostridial disease, weaned calves against *M. haemolytica*, and suckling calves against *H. somni* than small herds (Table 3.5). Weaned calves were more likely to be vaccinated against BVDV, IBR, BRSV, PI3, *M. haemolytica* +/- *P. multocida* in herds that retained most of their calves for more than 2 months (Table 3.5). Herds that were strictly commercial were less likely to vaccinate weaned calves against BVDV and breeding cattle against bovine genital campylobacteriosis and leptospirosis than herds that contained some seedstock (Table 3.5).

Herds that started calving in February and March were less likely to vaccinate weaned calves against BVDV, IBR, BRSV, and PI3 than herds that started calving in January (Table 3.6). Herds that calved later in the spring (April and May) were less likely to vaccinate cows against calf scours compared to those that calved in January. Finally, herds that calved in March were more likely to administer IBR vaccines to suckling calves, compared to those that calved in January (Table 3.6).

3.4.5 Regional vaccination trends

Generally, reported vaccination practices were consistent between eastern and western herds with a few differences (Table 3.7). Western herds were substantially more likely to administer clostridial vaccines to all classes of cattle. Eastern herds were more likely to vaccinate cows for *M. haemolytica* +/- *P. multocida,* but only 1 western and 4 eastern herds reported use of this vaccine. While 40% of western producers administered footrot vaccines to their bulls, eastern herds did not report use of this vaccine. Western producers were more likely to vaccinate calves either before or after weaning against *M. haemolytica* and *P. multocida*, and suckling calves for *H. somni* than eastern producers. Thirty-one percent of western herds (28/91) and 38% of eastern herds (15/40) administered at least one IN IBR/BRSV/PI3 vaccine to calves prior to weaning.

3.4.6 Motivations for vaccine use

The top three factors that producers considered when deciding what vaccines to use on their operations were the importance of disease in the herd, economic benefits of using the vaccine, and potential to minimize treatment rate and antimicrobial use (Table 3.8). Eighteen producers (14%) independently identified advice from their veterinarian as a top influencing factor in vaccine choice. Producer's top three reasons for choosing whether to vaccinate suckling calves were convenience, need for adequate labour to handle calves, and history of calf health problems (Table 3.8).

3.4.7 Vaccine use and associations with calf productivity and nonpregnant breeding females

Calf morbidity, treatment, and mortality rates were available for 124 of the 131 herds in this cohort and vaccine use was examined for association with these outcomes (Table 3.9). Herds that vaccinated suckling calves against clostridial disease had a lower risk of calf mortality, and herds that vaccinated against BVDV and *M. haemolytica* (+/- *P. multocida*), had a higher risk of pneumonia in calves. No associations were found between vaccine use and risk of calf scours or nonpregnancy in breeding females.

3.5 Discussion

This paper presents the first detailed picture of vaccine use practices in cow-calf herds from across Canada. Differences in vaccine use between eastern and western herds were limited.

Identified differences in clostridial vaccination echoed previous reports where herds in Ontario were less likely to use clostridial vaccines than western herds (25, 33). While regional differences in some vaccines might be due to herd size, facilities, and labour availability, the risk of clostridial diseases is ubiquitous across the country.

Vaccination of the cow herd was higher compared to 2015/2016 reports from eastern provinces (18-20%) but was similar to reports of the same year from western provinces (25, 33). Most producers vaccinated their cows against viruses associated with respiratory and reproductive diseases; however, there are still herds in which these vaccines are not utilized. Less than one-third of producers vaccinated against *Campylobacter* and 35% of herds vaccinated against *Leptospira*. Producers that used community pastures were more likely to vaccinate cows against *Campylobacter* than those that did not. Annual *Campylobacter* and *Leptospira* revaccination are not considered core vaccines by the American Association of Bovine Practitioners, but are recommended for herds considered to be at high risk for either of these infections due to biosecurity challenges, comingling on community pastures or geographic location (19, 20). Waldner et al. reported similar vaccination trends for BVDV in cows, but higher levels of bacterial respiratory vaccines in cows (38).

Vaccination of bulls was less common than for cows and replacement heifers and continues to present an opportunity for improvement. Commonly, bulls were vaccinated against BVDV, IBR, BRSV, PI3, clostridial pathogens, footrot (*Fusobacterium*) and *Leptospira* spp. Most producers followed recommended practices, and vaccinated bulls prior to breeding. According to a survey of US and Canadian beef cattle veterinarians, 79% recommended vaccinating bulls at the same time as the cow herd (19). The proportion of western producers that vaccinated bulls for at least one target was at a similar level to a 2016 study (25); however, the proportion that vaccinated against BVDV, IBR, PI3, BRSV, bovine genital campylobacteriosis, and clostridial diseases seemed to be moderately higher. Compared to eastern Canadian herds in 2015/2016, overall vaccination of bulls was higher by 15-24% (33). It was more common for Canadian herds to administer one or more vaccines to bulls (83%) than US cow-calf herds surveyed in 2016 (44%) (39).

While clostridial vaccines are considered a core vaccine for bulls, only 47% of producers vaccinated their bulls during 2020 (20). Some producers are potentially boosting clostridial vaccines every 2 or more years rather than vaccinating annually. Thus, this survey might have overlooked herds where 2020 was an "off" year for clostridial vaccinations. Clostridial vaccine use was only modestly higher in cows. Although most replacement heifer vaccination practices were similar to that reported for cows, the proportion of herds reporting clostridial vaccine use was higher for heifers than for cows. This might reflect more consistent annual vaccination protocols for heifers. While not all herds report annual use of clostridial vaccines, all clostridial vaccines approved for use in Canada recommend annual revaccination in adult beef cattle. Biannual vaccination with these products is an off-label recommendation.

Replacement heifers were more commonly vaccinated than cows and bulls for all other core vaccines, and these were given almost exclusively as MLV vaccines, prior to breeding. No heifers in this cohort of herds were administered a MLV BVDV/IBR/BRSV/PI3 vaccine at pregnancy testing without at least one prior vaccination of the same kind. More than 9 out of 10 producers using MLV at pregnancy testing provided two prior doses to their heifers as recommended by at least one commonly used commercial vaccine (40). This is a good indication that many producers are aware of the potential risks of MLV vaccines and label recommendations for proper use (20). However, while more replacement heifers than cows were vaccinated for scours or calf diarrhea pathogens, less than half received the second dose recommended by product labels.

Vaccination of both suckling and weaned calves against at least one pathogen has increased since previous reports of herds from western Canada, and northern Ontario and Quebec (25, 34). The potential benefits of vaccinating suckling calves against BRD pathogens particularly for herds with a history of BRD likely influenced vaccine choices (30). Many producers identified the "importance of the disease in the herd" as an influential factor when determining vaccine protocols. The most common vaccines administered to calves were the core vaccines recommended by the AABP (BVDV, IBR, BRSV, PI3 and clostridial vaccines) (20).

Modified-live vaccines were used almost exclusively in calves for all viral targets. Most (90-93%) surveyed North American beef cattle veterinarians recommended the use of MLV vaccines in calves prior to and after weaning (19). According to previous reports of western herds, modified-live BVDV vaccines were used exclusively in both suckling calves and weaned calves (25). Vaccine use differentiated by type (MLV or inactivated/killed) has not been reported for eastern provinces.

Compared to western cow-calf herd vaccination benchmarks reported in 1997 and 1998, the current vaccination landscape is unrecognisable (41). The focus of calf vaccination has shifted to respiratory disease. Compared to 1997/98, vaccination of calves in 2020 was at a higher proportion for all reported targets except for *P. multocida*. This includes BVDV (↑ 53%), IBR (↑49%), PI3 (↑54%), BRSV (↑62%), and *H. somni* (↑7%) (41). Compared to western Canadian herds in 2016, the proportion of herds administered one dose to suckling calves was at a similar proportion; IBR, BRSV and PI3 vaccination was higher (7%), while BVDV vaccination was slightly lower (4%), but the proportion of producers who boosted calves prior to weaning was higher for all viral respiratory targets (4-13%) (25). This is likely attributed to the increased use of intranasal respiratory vaccines, which do not contain BVDV. Use of intranasal viral respiratory vaccines at birth (21%) was higher compared to previous reports for western Canada (9%), Ontario (12%) and Atlantic Canada (14%) (25, 32, 33). Compared to parenteral vaccines, intranasal respiratory vaccines administered in young calves has been shown to produce a better immune priming response in the face of maternal antibodies (13, 14, 42, 43). Protection provided by intranasal respiratory vaccines may be unpredictable and short term (44).

Before weaning, 47% of herds boosted IBR/BRSV/PI3 vaccines, but less than 20% boosted clostridial vaccines. Most commercially available IBR/BRSV/PI3 and clostridial vaccines approved for use in Canadian calves require a second dose after initial vaccination. Calves from herds given an initial IBR/BRSV/PI3 vaccines before 3 months of age were more likely to receive a second vaccine prior to weaning.

Producers identified “convenience (calves were being handled for another reason)” as the top factor influencing their decision to vaccinate nursing calves. Lack of labour, time, access to facilities, weather, or the desire to minimize handling stress might have contributed to limited vaccine boosting in nursing calves. Further, due to a lack of preconditioning incentives for Canadian producers, the largest economic return from optimizing protection due to vaccination is not seen by the cow-calf producer, but rather the in feedlot. Vaccination prior to weaning as part of a preconditioning program has shown to reduce the incidence of respiratory disease and increase average daily gain in the feedlot (26, 27).

Bacterial respiratory vaccines including *M. haemolytica* and *P. multocida* were less common than viral respiratory vaccines which is expected as these vaccines are considered “risk based”, and recommended on an individual herd basis (20). Most herds administered this vaccine after 2 weeks of age and before weaning. Surveyed North American bovine veterinarian's recommendations for best timing of initial *M. haemolytica* vaccination were inconsistent; recommended times were at branding (45%), before weaning (77%), and after weaning (49%) (19).

The apparent association between vaccination of suckling calves against BVDV or *M. haemolytica* and an increased risk of pneumonia in suckling calves is consistent with previous western Canadian herd surveys that reported beef calves vaccinated for BRD near birth were more likely to be treated for BRD (38). As was noted earlier, producers reported using vaccines in response to the importance of disease in their herds. This association is likely explained by this factor, whereby herds with a historical or ongoing respiratory disease problem were more likely to use these vaccines. Further, in 20% of herds from the current study these vaccines were first administered after 3 months of age after and following the first peak risk for respiratory disease (38).

Conversely, while the reduced risk of calf mortality in suckling calves that were vaccinated against clostridial disease could reflect vaccine success, vaccine use could also potentially reflect overall herd management. One earlier study from western Canada reported the potential benefits of vaccinating cows for clostridial diseases and subsequent protection of the calf crop, and while clostridial vaccines are generally recognized as being highly effective this is the first specific report from Canadian beef herds documenting a beneficial association with use (5).

The survey response rate was slightly lower than the 2016 western Canadian cow-calf survey (88% vs 81%) and might have been impacted by the severe drought related pressures placed particularly on western producers in 2021 during survey collection (25). Due to the criteria to be enrolled in the study, this group of producers likely represents a progressive subset of producers and might not be reflective of all Canadian cow-calf producers. This cohort of producers represents the early adopters of innovative practices and are therefore potentially an overrepresentation of vaccine use in the average Canadian cow-calf herd. It is unknown whether responses to the survey or overall vaccination rates were affected by the COVID-19 pandemic or if management decisions were negatively impacted by vaccine hesitancy surrounding viral respiratory vaccines. While surveys suffer from recall bias, producers were provided with color photos and a book to help them find the name of the products used if they didn't have access to receipts or records. Misclassification was also managed by asking the producers to report the actual trade name of the product used from their receipts and records rather than asking them what diseases they vaccinated for. The trade names were then re-coded to capture the vaccine components by the study team.

Vaccine use across Canada has shown significant improvement over the past few decades. Cow-calf producers generally followed recommended vaccination protocols for all core vaccines. The number of herds that vaccinated animals increased for nearly all cattle groups since previous reports. One notable change is the increased use of intranasal respiratory vaccines, specifically in neonatal calves. While many positive changes have been made in the industry, there are still some areas where improvement is needed. Producers should be encouraged to vaccinate calves against respiratory disease before 3 months of age, in consultation with their veterinarian, to allow more time for the vaccine to have an effect before high-risk periods for the disease and to allow time to administer a second dose prior to weaning. The literature is scant as to the relative benefits of mucosal vaccination of calves near the time of birth, as well as for the optimal type of follow up vaccination. Recently several projects observing mucosal prime systemic boost have found a benefit for mucosal priming of neonates that is variable depending on the pathogen and form of booster vaccine used; a benefit for mucosal prime and systemic boost has been found for BRSV, bovine coronavirus and BVDV (14-16, 18). Mucosal prime and systemic boost, of neonatal calves, has been shown to improve virus specific and neutralizing antibody concentrations and their booster responses for BRSV, BCoV and BVDV. Improved protection against disease has also been observed when primed and boosted calves were challenged with BRSV or BVDV type 2 (16, 18). More research is needed on the relative benefits of vaccinating calves near time of birth and optimal timing of a booster to minimize risks of respiratory disease associated with stress and increased animal density during activities such as artificial insemination (24, 38, 42).

While all classes of cattle were examined, this study contributes unique information on the types, timing and number of vaccine doses used in nursing calves from a cohort of privately owned herds. While participants likely represent a relatively progressive subset of producers, more producers reported vaccinating nursing calves for BRD as compared to previous work in similar cohorts. The results show that high adoption rates for preweaning vaccination is a reasonable goal for commercial cow-calf herds. However, there was very little consistency in vaccine protocols for nursing beef calves, highlighting opportunities to optimize vaccination timing for challenges specific to each operation such as the timing of calving season and resource limitations. In addition, protocols might vary depending on whether the primary goal of calf vaccination is to reduce disease following weaning, or in nursing calves either before or after summer pasture turnout.

3.6 Conclusions

To improve vaccine efficacy, producers must properly follow product labels instructions, specifically regarding administration of booster doses within the specified period. This issue was most apparent for clostridial vaccines in cows and bulls, and scours vaccines in bred heifers. Economic incentives for producers to vaccinate calves prior to feedlot entry should be a top priority for industry to ensure the long-term sustainability of Canadian beef production. There are still a small percentage of cow-calf producers that are not using the core viral vaccines for whom targeted technology transfer activities might be necessary. Finally, clostridial vaccines are underused in cows and bulls, particularly in eastern herds. These vaccines should be administered yearly to ensure cattle are fully protected and optimal clostridial transfer of antibodies.

3.7 References

1. Newcomer BW, Chamorro MF, and Walz PH. Vaccination of cattle against bovine viral diarrhea virus. Vet Microbiol 2017;206: 78-83.

2. Newcomer BW, Cofield LG, Walz PH, and Givens MD. Prevention of abortion in cattle following vaccination against bovine herpesvirus 1: A meta-analysis. Prev Vet Med 2017;138: 1-8.

3. Sanhueza JM, Wilson PR, Benschop J, Collins-Emerson JM, and Heuer C. Meta-analysis of the efficacy of Leptospira serovar Hardjo vaccines to prevent urinary shedding in cattle. Prev Vet Med 2018;153: 71-76.

4. Waldner C. Cow attributes, herd management, and reproductive history events associated with abortion in cow-calf herds from Western Canada. Theriogenology 2014;81 (6): 840-848.

5. Waldner C, Jelinski M, and McIntyre-Zimmer K. Survey of western Canadian beef producers regarding calf-hood diseases, management practices, and veterinary service usage. Can Vet J 2013;54: 599-564.

6. Waldner CL and Garcia Guerra A. Cow attributes, herd management, and reproductive history events associated with the risk of nonpregnancy in cow-calf herds in Western Canada. Theriogenology 2013;79 (7): 1083-1094.

7. Newcomer BW, Walz PH, Givens MD, and Wilson AE. Efficacy of bovine viral diarrhea virus vaccination to prevent reproductive disease: A meta-analysis. Theriogenology 2015;83 (3): 360-365.e361.

8. Troxel TR, Burke GL, Wallace WT, et al. Clostridial vaccination efficacy on stimulating and maintaining an immune response in beef cows and calves. J Anim Sci 1997;75 (1): 19-25.

9. Capik SF, Moberly HK, and Larson RL. Systematic review of vaccine efficacy against Mannheimia haemolytica, Pasteurella multocida, and Histophilus somni in North American cattle. Bov Pract 2021;55 (2): 125-133.

10. Woolums A. Immune management and vaccination of the preweaning beef calf. American Association of Bovine Practitioners Conference Year

11. Gow S, Waldner C, and Ross C. The effect of treatment duration on weaning weights in a cow-calf herd with a protracted severe outbreak of diarrhea in calves. Can Vet J 2005;46 (5): 418-423, 425-416.

12. Maier GU, Breitenbuecher J, Gomez JP, Samah F, Fausak E, and Van Noord M. Vaccination for the prevention of neonatal calf diarrhea in cow-calf operations: a scoping review. Vet Anim Sci 2022;15: 100238.

13. Erickson NEN, Ellis J, Waldner C, et al. Comparison of bovine viral diarrhea virus-specific antibody responses of young beef calves vaccinated with either modified live virus or inactivated virus regimens. Can Vet J 2020;61 (8): 871-874.

14. Erickson NEN, Berenik A, Lardner H, et al. Evaluation of bovine respiratory syncytial virus (BRSV) and bovine herpesvirus (BHV) specific antibody responses between heterologous and homologous prime-boost vaccinated western Canadian beef calves. Can Vet J 2021;62: 37-44.

15. Erickson NEN, Lacoste S, Sniatynski M, Waldner C, and Ellis J. Comparison of virus neutralizing and virus specific ELISA antibody responses among bovine neonates differentially primed and boosted against Bovine coronavirus, 2023. In press.

16. Erickson NEN, Godson D, Gow S, Lacoste S, Waldner C, and Ellis J. Comparative efficacy of modified-live and inactivated vaccines in boosting disease-sparing responses to bovine viral diarrhea virus challenge in neonatally mucosally primed weanling beef calves. Can Vet J 2023;64 (4): 321-328.

17. Martinez DA, Newcomer B, Passler T, and Chamorro MF. Efficacy of Bovine Respiratory Syncytial Virus vaccines to reduce morbidity and mortality in calves within experimental infection models: a systematic review and meta-analysis. Front Vet Sci 2022;9: 906636.

18. Ellis J, Gow S, Berenik A, Lacoste S, and Erickson N. Comparative efficacy of modified-live and inactivated vaccines in boosting responses to bovine respiratory syncytial virus following neonatal mucosal priming of beef calves. Can Vet J 2018;59 (12): 1311-1319.

19. Fike GD, Simroth JC, Thomson DU, Schwandt EF, Spare R, and Tarpoff AJ. A survey of recommended practices made by veterinary practitioners to cow-calf operations in the United States and Canada. Prof Anim Sci 2017;33 (6): 716-728.

20. AABP Vaccination Guidelines. American Association of Bovine Practitioners. Ashland, OH. Available from http://www.aabp.org/committees/resources/VaccGuidelines2021.pdf.

21. "Western Canadian Cow-Calf Survey II". WCCCSN. University of Saskatchewan. Available from http://westernbeef.org/pdfs/wcccs/WCdnSurveyII_FINAL.pdf.

22. Davidson TM and Canfax Research Services. Beef Cattle Research Council (BCRC): Adoption Rates of Recommended Practices by Cow-Calf Operators in Canada, 2019.

23. Brault SA, Hannon SJ, Gow SP, et al. Antimicrobial Use on 36 Beef Feedlots in Western Canada: 2008–2012. Front Vet Sci 2019;6.

24. Fossen JD, Campbell JR, Gow SP, Erickson N, and Waldner CL. Antimicrobial use in Canadian cow-calf herds. Vet Sci 2023;10 (5).

25. Waldner CL, Parker S, and Campbell JR. Vaccine usage in western Canadian cow-calf herds. Can Vet J 2019;60 (4): 414-422.

26. Schumaher TF, Cooke RF, Brandao AP, et al. Effects of vaccination timing against respiratory pathogens on performance, antibody response, and health in feedlot cattle. J Anim Sci 2019;97 (2): 620-630.

27. Lippolis KD, Cooke RF, Schubach KM, et al. Altering the time of vaccination against respiratory pathogens to enhance antibody response and performance of feeder cattle. J Anim Sci 2016;94 (9): 3987-3995.

28. O'Connor AM, Hu D, Totton SC, et al. A systematic review and network meta-analysis of bacterial and viral vaccines, administered at or near arrival at the feedlot, for control of bovine respiratory disease in beef cattle. Anim Health Res Rev 2019;20 (2): 143-162.

29. Larson RL and Step DL. Evidence-based effectiveness of vaccination against Mannheimia haemolytica, Pasteurella multocida, and Histophilus somni in feedlot cattle for mitigating the incidence and effect of bovine respiratory disease complex. Vet Clin North Am Food Anim Pract 2012;28 (1): 97-106, 106e101-107, ix.

30. Theurer ME, Larson RL, and White BJ. Systematic review and meta-analysis of the effectiveness of commercially available vaccines against bovine herpesvirus, bovine viral diarrhea virus, bovine respiratory syncytial virus, and parainfluenza type 3 virus for mitigation of bovine respiratory disease complex in cattle. J Am Vet Med Assoc 2015;246 (1): 126-142.

31. Griffin CM, Scott JA, Karisch BB, et al. A randomized controlled trial to test the effect of on-arrival vaccination and deworming on stocker cattle health and growth performance. Bov Pract (Stillwater) 2018;52 (1): 26-33.

32. Maritime Beef Council. Atlantic Cow-Calf Production Survey Aggregate Results, 2018.

33. Ontario Cow-Calf 2015/16 Production Survey (OCC). OCC: University of Guelph. 2018. Available from https://www.beefresearch.ca/files/pdf/Ontario%20Cow-Calf%20Summary%20Nov%2012%202018.pdf.

34. Lamothe S and North Haven Solutions. Northern beef study: Northern Ontario and Northern Quebec beef cow-calf production. 2018.

35. Waldner CL, Parker S, and Campbell JR. Identifying performance benchmarks and determinants for reproductive performance and calf survival using a longitudinal field study of cow-calf herds in western Canada. PLoS One 2019;14 (7): e0219901.

36. Johnson P, McLeod L, Campbell J, Rousseau M, Larson K, and Waldner C. Estimating the sensitivity and specificity of serum ELISA and pooled and individual fecal PCR for detecting Mycobacterium avium subspecies paratuberculosis in Canadian cow-calf herds using Bayesian latent class models. Front Vet Sci 2022;9: 937141.

37. Compendium of Veterinary Products - Canada edition Beef Cattle Biological Chart. Available from https://zoetis.cvpservice.com/chartindex/main?type=bio.

38. Waldner CL, Wilhelm B, Windeyer MC, Parker S, and Campbell J. Improving beef calf health: frequency of disease syndromes, uptake of management practices following calving, and potential for antimicrobial use reduction in western Canadian herds. Transl Anim Sci 2022;6 (4): txac151.

39. USDA. Beef 2017, "Beef cow-calf health and management practices in the United States, 2017, report 2". Fort Collins, CO. , 2020; #.782.1119.

40. BOVI-SHIELD® GOLD FP® 5 10 DOSES. Zoetis CA. Available from https://www2.zoetis.ca/species/bovine/products-and-solutions/bovi-shield-gold-fp-5-10-doses.

41. Alberta Cow-Calf Audit 1997/98. Alberta Agriculture and Rural Development. Available from http://westernbeef.org/pdfs/economics/AB_CowCalf_Audit.pdf.

42. Woolums AR, Berghaus RD, Berghaus LJ, et al. Effect of calf age and administration route of initial multivalent modified-live virus vaccine on humoral and cell-mediated immune responses following subsequent administration of a booster vaccination at weaning in beef calves. Am J Vet Res 2013;74 (2): 343-354.

43. Chamorro MF, Woolums A, and Walz PH. Vaccination of calves against common respiratory viruses in the face of maternally derived antibodies (IFOMA). Anim Health Res Rev 2016;17 (2): 79-84.

44. Windeyer MC and Gamsjäger L. Vaccinating calves in the face of maternal antibodies: challenges and opportunities. Vet Clin North Am Food Anim Pract 2019;35 (3): 557-573.

1

3.8 Tables

Table 3.1 Summary of vaccines and booster doses administered to bulls, cows and replacement heifers from January 1 to December 31, 2020 in Canadian cow-calf herds reported as proportion of herds (and number of herds) (n = 131 herds).

Vaccine target	Bulls		Cows		Replacement heifers	
	First vaccine	Second vaccine	First vaccine	Second vaccine	First vaccine	Second vaccine
BVDV Type 1 and 2, IBR, BRSV and PI3	0.75 (98)	0.03 (4)	0.92 (121)	0.05 (6)	0.92 (120)	0.18 (23)
Mannheimia haemolytica	0.08 (11)	0 (0)	0.04 (5)	0 (0)	0.08 (10)	0 (0)
Pasteurella multocida	0.02 (2)	0 (0)	0 (0)	0 (0)	0.01 (1)	0 (0)
Histophilus somni	0.16 (21)	0 (0)	0.18 (24)	0.02 (2)	0.22 (29)	0.05 (7)
Campylobacter fetus	0.18 (23)	0 (0)	0.21 (28)	0.02 (2)	0.23 (30)	0.05 (7)
Leptospira spp.	0.27 (35)	0.01 (1)	0.35 (46)	0.04 (5)	0.36 (47)	0.08 (11)
Coronavirus	0 (0)	0 (0	0.50 (66)	0.07 (9)	0.53 (70)	0.24 (31)
Rotavirus	0 (0)	0 (0)	0.50 (66)	0.07 (9)	0.53 (70)	0.24 (31)
Escherichia coli	0 (0)	0 (0)	0.44 (58)	0.07 (9)	0.47 (62)	0.17 (22)
Cl. perfringens (scours)	0 (0)	0 (0)	0.05 (7)	0.02 (2)	0.06 (8)	0.04 (5)
Clostridial vaccine (any)	0.50 (65)	0.02 (3)	0.59 (77)	0.02 (2)	0.66 (86)	0.09 (12)
Cl. 7-way[a]	0.08 (11)	0 (0)	0.07 (9)	0 (0)	0.09 (12)	0.01 (1)
Cl. 8-way[b]	0.15 (19)	0 (0)	0.16 (21)	0.01 (1)	0.21 (28)	0.02 (3)
Cl. 8-way (*Cl. tetani*)[c]	0.17 (22)	0.02 (3)	0.19 (25)	0 (0)	0.23 (30)	0.03 (5)
Cl. 9-way[d]	0.12 (16)	0 (0)	0.14 (18)	0.01 (1)	0.17 (22)	0.02 (3)
Cl. tetani	0.29 (38)	0.02 (3)	0.33 (43)	0.01 (1)	0.40 (52)	0.06 (8)
Anthrax	0.02 (3)	0 (0)	0.02 (3)	0 (0)	0.02 (3)	0 (0)
Fusobacterium	0.31 (41)	0.02 (3)	0.01 (1)	0 (0)	0 (0)	0 (0)
Moraxella bovis	0.02 (2)	0 (0)	0.02 (2)	0 (0)	0.01 (1)	0 (0)
Papillomavirus	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Proportion (n) of herds reporting use of any vaccine	**0.83 (109)**	**0.05 (7)**	**0.97 (127)**	**0.10 (13)**	**0.95 (124)**	**0.34 (44)**

[a] 7-way contains *Cl. chauvoei*, *Cl. novyi*, *Cl. perfringens* Types B, C, D, *Cl. septicum*, *Cl. sordellii*; [b] 8-way contains 7-way plus *Cl. haemolyticum*; [c] 8-way (*Cl. tetani)* contains 7-way plus *Cl. haemolyticum* (*Cl. tetani* replaces *Cl. sordellii*); [d] 9-way contains 7-way plus *Cl. haemolyticum* and *Cl. Tetani*.

Table 3.2 Timing of vaccination and vaccine type administered to bulls, cows, and replacement heifers for common vaccine targets used in 131 Canadian cow-calf herds. Reported as proportion of herds that vaccinated (number of herds).

Vaccine timing	BVDV	IBR, BRSV, and PI3	*Mh* +/- *Pm*[a]	*H. somni*	*Clostridia* spp.	Calf scours[b]	*Campylobacter* or *Leptospira* spp.	Footrot
Bulls								
▪ Before breeding	0.60 (78)	0.60 (78)	0.04 (5)	0.15 (19)	0.40 (53)	0 (0)	0.24 (32)	0.31 (41)
▪ After breeding	0.15 (20)	0.15 (20)	0.03 (4)	0.02 (2)	0.07 (9)	0 (0)	0.05 (7)	0 (0)
Modified live vaccine	0.52 (68)	0.67 (88)	n/a	n/a	n/a	n/a	n/a	n/a
▪ Before breeding	0.52 (68)	0.54 (71)	n/a	n/a	n/a	n/a	n/a	n/a
▪ After breeding	0.11 (15)	0.13 (17)	n/a	n/a	n/a	n/a	n/a	n/a
Inactivated/killed vaccine	0.11 (15)	0.08 (10)	0.07 (9)	0.16 (21)	0.51 (67)	n/a	0.30 (39)	0.31 (41)
▪ Before breeding	0.08 (10)	0.05 (7)	0.04 (5)	0.15 (19)	0.40 (53)	0 (0)	0.24 (32)	0.31 (41)
▪ After breeding	0.04 (5)	0.02 (3)	0.03 (4)	0.02 (2)	0.07 (9)	0 (0)	0.05 (7)	0 (0)
Cows								
▪ Before breeding	0.54 (71)	0.54 (71)	0.02 (2)	0.11 (14)	0.21 (28)	0.01 (1)	0.25 (33)	0.01 (1)
▪ At pregnancy testing	0.27 (36)	0.28 (37)	0.01 (1)	0.03 (4)	0.22 (29)	0.12 (16)	0.08 (11)	0 (0)
▪ Before calving	0.14 (18)	0.21 (28)	0.01 (1)	0.05 (7)	0.15 (20)	0.44 (57)	0.08 (10)	0 (0)
Modified live vaccine	0.76 (99)	0.84 (110)	n/a	n/a	n/a	n/a	n/a	n/a
▪ Before breeding	0.51 (67)	0.53 (70)	n/a	n/a	n/a	n/a	n/a	n/a
▪ At pregnancy testing	0.13 (16)	0.19 (24)	n/a	n/a	n/a	n/a	n/a	n/a
▪ Before calving	0.10 (13)	0.19 (25)	n/a	n/a	n/a	n/a	n/a	n/a
Inactivated/killed vaccine	0.21 (28)	0.13 (17)	0.04 (5)	0.18 (24)	0.59 (77)	0.53 (69)	0.39 (51)	0.01 (1)
▪ Before breeding	0.03 (4)	0.01 (1)	0.02 (2)	0.11 (14)	0.21 (28)	0.01 (1)	0.25 (33)	0.01 (1)
▪ At pregnancy testing	0.15 (20)	0.10 (13)	0.01 (1)	0.03 (4)	0.22 (29)	0.12 (16)	0.08 (11)	0 (0)
▪ Before calving	0.04 (5)	0.02 (3)	0.01 (1)	0.05 (7)	0.15 (20)	0.44 (57)	0.08 (10)	0 (0)
Replacement heifers								
▪ Before breeding	0.82 (108)	0.81 (106)	0.05 (7)	0.19 (25)	0.46 (60)	0.02 (2)	0.34 (45)	0 (0)
▪ At pregnancy testing	0.21 (28)	0.20 (26)	0.02 (3)	0.04 (5)	0.22 (29)	0.28 (37)	0.06 (8)	0 (0)
▪ Before calving	0.07 (9)	0.11 (14)	0 (0)	0.02 (3)	0.14 (18)	0.50 (66)	0.02 (3)	0 (0)
Modified live vaccine	0.85 (111)	0.89 (117)	0.01 (1)	n/a	n/a	n/a	n/a	n/a
▪ Before breeding	0.76 (100)	0.79 (103)	0.01 (1)	n/a	n/a	n/a	n/a	n/a
▪ At pregnancy testing	0.13 (17)	0.17 (22)	0 (0)	n/a	n/a	n/a	n/a	n/a
▪ Before calving	0.05 (6)	0.09 (12)	0 (0)	n/a	n/a	n/a	n/a	n/a
Inactivated/killed vaccine	0.16 (20)	0.10 (13)	0.07 (9)	0.22 (29)	0.66 (86)	0.55 (72)	0.40 (52)	0 (0)
▪ Before breeding	0.06 (8)	0.04 (5)	0.05 (6)	0.19 (25)	0.46 (60)	0.02 (2)	0.34 (45)	0 (0)
▪ At pregnancy testing	0.08 (11)	0.05 (7)	0.02 (3)	0.04 (5)	0.22 (29)	0.28 (37)	0.06 (8)	0 (0)
▪ Before calving	0.02 (3)	0.02 (2)	0 (0)	0.02 (3)	0.14 (18)	0.50 (66)	0.02 (3)	0 (0)

[a] *Mannheimia haemolytica* with or without *Pasteurella multocida*; b Scours: BCoV, BRV, E. coli, and/or *Clostridium perfringens*; c *Campylobacter fetus* or *Leptospira* spp. ; n/a= not applicable: no registered MLV vaccine available for listed bacterial target

Table 3.3 Summary of initial vaccine dose and type and booster doses administered to suckling and weaned calves from January 1 to December 31, 2020 in Canadian cow-calf herds reported as proportion of herds (and number of herds).

	All calves (n=131)		Suckling calves (n=131)		Weaned calves					
					All herds (n=131)		Retained[a] (n=69)		Did not retain (n=62)	
Vaccine target	First vaccine	Second vaccine	First vaccine	Second vaccine	First vaccine	Second vaccine	First vaccine	Second vaccine	First vaccine	Second vaccine
BVDV Type 1 & 2	0.93 (122)	0.61 (80)	0.78 (102)	0.30 (39)	0.57 (75)	0.05 (6)	0.65 (45)	0.07 (5)	0.48 (30)	0.02 (1)
IBR, BRSV & PI3	0.95 (125)	0.77 (101)	0.92 (120)	0.47 (61)	0.58 (76)	0.05 (6)	0.67 (46)	0.07 (5)	0.48 (30)	0.02 (1)
M. haemolytica	0.62 (81)	0.28 (37)	0.56 (73)	0.27 (36)	0.30 (39)	0.02 (3)	0.39 (27)	0.04 (3)	0.19 (12)	0 (0)
P. multocida	0.19 (25)	0.16 (21)	0.18 (23)	0.04 (5)	0.05 (6)	0.01 (1)	0.04 (3)	0.01 (1)	0.05 (3)	0 (0)
H. somni	0.43 (56)	0.16 (21)	0.40 (52)	0.08 (10)	0.16 (21)	0.08 (11)	0.22 (15)	0.13 (9)	0.08 (5)	0.03 (2)
Campylobacter fetus	0.02 (3)	0 (0)	0.02 (2)	0 (0)	0.02 (2)	0 (0)	0.01 (1)	0 (0)	0.02 (1)	0 (0)
Leptospira spp.	0.07 (9)	0.02 (3)	0.03 (4)	0.01 (1)	0.06 (8)	0.02 (2)	0.07 (5)	0.01 (1)	0.05 (3)	0.02 (1)
Coronavirus	0.06 (8)	0.01 (1)	0.06 (8)	0.01 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Rotavirus	0.06 (8)	0.01 (1)	0.06 (8)	0.01 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Escherichia coli	0.02 (2)	0.01 (1)	0.02 (2)	0.01 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cl. perfringens	0.02 (2)	0.01 (1)	0.02 (2)	0.01 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Clostridial vaccine	0.88 (115)	0.46 (60)	0.87 (114)	0.26 (34)	0.27 (36)	0.02 (2)	0.33 (23)	0.03 (2)	0.21 (13)	0 (0)
Cl. 7-way[b]	0.27 (36)	0.21 (27)	0.27 (36)	0.08 (10)	0.20 (26)	0 (0)	0.23 (16)	0 (0)	0.16 (10)	0 (0)
Cl. 8-way[c]	0.27 (35)	0.11 (15)	0.27 (35)	0.10 (13)	0.02 (2)	0 (0)	0.03 (2)	0 (0)	0 (0)	0 (0)
Cl. 8-way (*Cl. tetani*)[d]	0.21 (28)	0.05 (6)	0.21 (28)	0.05 (6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cl. 9-way[e]	0.13 (17)	0.09 (12)	0.12 (16)	0.04 (5)	0.06 (8)	0.02 (2)	0.07 (5)	0.03 (2)	0.05 (3)	0 (0)
Cl. tetani	0.34 (45)	0.14 (18)	0.34 (44)	0.08 (11)	0.06 (8)	0.02 (2)	0.07 (5)	0.03 (2)	0.05 (3)	0 (0)
Anthrax	0.02 (2)	0 (0)	0.02 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Fusobacterium	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.01 (1)	0 (0)	0 (0)
Moraxella bovis	0.02 (3)	0 (0)	0.02 (2)	0 (0)	0.01 (1)	0 (0)	0.01 (1)	0 (0)	0 (0)	0 (0)
Papillomavirus	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Proportion (n) of herds reporting use of any vaccine	**0.99** (130)	**0.82** (108)	**0.98** (129)	**0.56** (74)	**0.66** (87)	**0.11** (15)	**0.77** (53)	**0.17** (12)	**0.55** (34)	**0.05** (3)

[a] Producer retained >50% of the calf herd for ≥2 months post weaning; [b] 7-way contains *Cl. chauvoei*, *Cl. novyi*, *Cl. perfringens* Types B, C, D, *Cl. septicum*, *Cl. sordellii*; [c] 8-way contains 7-way plus *Cl. haemolyticum*; [d] 8-way (*Cl. tetani)* contains 7-way plus *Cl. haemolyticum* (*Cl. tetani* replaces *Cl. sordellii*); [e] 9-way contains 7-way plus *Cl. haemolyticum* and *Cl. Tetani*.

Table 3.4 Vaccination timing and vaccine type for all vaccine doses administered to weaned and suckling calves for common vaccine targets used in 131 Canadian cow-calf herds. Reported as proportion of herds that vaccinated (number of herds).

Vaccination timing	BVDV types 1 or 2	IBR, BRSV, and PI3	*Mh* +/- *Pm* [a]	*H. somni*	*Clostridia* spp.
Suckling calves					
▪ Birth – 2 weeks	0 (0)	0.21 (27)	0.07 (9)	0 (0)	0.04 (5)
▪ 2 weeks – 3 months	0.50 (65)	0.60 (79)	0.42 (55)	0.31 (40)	0.67 (88)
▪ >3 months	0.52 (68)	0.62 (81)	0.40 (53)	0.23 (30)	0.42 (55)
Modified live vaccine	0.75 (98)	0.91 (119)	0.18 (23)	n/a	n/a
▪ Birth – 2 weeks	(0)	0.20 (26)	0.07 (9)	n/a	n/a
▪ 2 weeks – 3 months	0.49 (64)	0.60 (78)	0.08 (11)	n/a	n/a
▪ >3 months	0.50 (65)	0.62 (81)	0.08 (10)	n/a	n/a
Inactivated/killed vaccine	0.03 (4)	0.02 (2)	0.47 (61)	0.40 (52)	0.87 (114)
▪ Birth – 2 weeks	0 (0)	0.01 (1)	0.01 (1)	0 (0)	0.04 (5)
▪ 2 weeks – 3 months	0.01 (1)	0.01 (1)	0.34 (44)	0.31 (40)	0.67 (88)
▪ >3 months	0.02 (3)	0 (0)	0.33 (43)	0.23 (30)	0.42 (55)
Intranasal vaccine	n/a	0.33 (43)	0.10 (13)	n/a	n/a
▪ Birth – 2 weeks	n/a	0.20 (26)	0.07 (9)	n/a	n/a
▪ 2 weeks – 3 months	n/a	0.14 (18)	0.03 (4)	n/a	n/a
▪ >3 months	n/a	0.03 (4)	0.01 (1)	n/a	n/a
Weaned calves					
▪ At weaning	0.40 (52)	0.40 (52)	0.20 (26)	0.16 (21)	0.20 (26)
▪ After weaning	0.27 (35)	0.23 (30)	0.16 (21)	0.08 (11)	0.09 (12)
Modified live vaccine	0.56 (73)	0.57 (75)	0.05 (6)	n/a	n/a
▪ At weaning	0.38 (50)	0.41 (54)	0.02 (3)	n/a	n/a
▪ After weaning	0.26 (34)	0.21 (28)	0.02 (3)	n/a	n/a
Inactivated/killed vaccine	0.02 (3)	0.02 (2)	0.30 (39)	0.27 (21)	0.27 (36)
▪ At weaning	0.02 (2)	0.01 (1)	0.18 (23)	0.16 (21)	0.20 (26)
▪ After weaning	0.01 (1)	0.02 (2)	0.14 (18)	0.08 (11)	0.09 (12)
Intranasal vaccine	n/a	0.02 (3)	0 (0)	n/a	n/a
▪ At weaning	n/a	0.02 (3)	0 (0)	n/a	n/a
▪ After weaning	n/a	0.01 (1)	0 (0)	n/a	n/a

[a] *Mannheimia haemolytica* with or without *Pasteurella multocida*; n/a= not applicable: no registered MLV vaccine available for listed bacterial target

Table 3.5 Summary of unconditional associations between breeding cow herd size, calf retention and operation type on vaccine use in Canadian cow-calf herds (n=131).

Risk factor/Vaccine use		Odds Ratio††	95% CI		P-value
Breeding cow herd size					
▪ Cows vaccinated against clostridial disease	<100	(Ref)			**0.05**†
	100-300	1.86	0.86	4.02	0.12
	>300	3.71	1.25	11.0	**0.02**
▪ Heifers vaccinated against clostridial disease	<100	(Ref)			**0.01**†
	100-300	2.32	1.04	5.19	**0.04**
	>300	6.42	1.68	24.5	**<0.01**
▪ Weaned calves vaccinated against *M. haemolytica* +/- *P. multocida*	<100	(Ref)			**<0.01**†
	100-300	2.86	1.09	7.51	**0.03**
	>300	5.71	1.84	17.8	**<0.01**
▪ Weaned calves vaccinated against clostridial disease	<100	(Ref)			**0.04**†
	100-300	1.93	0.75	4.96	0.17
	>300	2.33	1.36	12.5	**0.01**
▪ Suckling calves vaccinated against H. somni	<100	(Ref)			**0.04**†
	100-300	2.39	1.04	5.47	**0.04**
	>300	3.45	1.22	9.72	**0.02**
▪ Suckling calves vaccinated against clostridial disease	<100	(Ref)			**0.01**†
	100-300	6.51	1.72	24.7	**<0.01**
	>300	3.77	0.77	18.5	0.10
Retained >50% of 2020 calf crop for ≥2 months post weaning vs did not retain >50% of calf crop					
▪ Heifers vaccinated against BVDV, IBR, BRSV, and PI3		8.81	1.05	73.8	0.05
▪ Weaned calves vaccinated against BVDV		2.43	1.20	4.93	**0.01**
▪ Weaned calves vaccinated against IBR, BRSV and PI3		2.13	1.05	4.32	**0.04**
▪ Weaned calves vaccinated against *M. haemolytica*		2.68	1.21	5.93	**0.02**
▪ Weaned calves vaccinated at least once for any target		2.73	1.29	5.78	**0.01**
100% commercial cow-calf herd vs commercial and purebred or purebred herd					
▪ Weaned calves vaccinated against BVDV		0.43	0.21	0.91	**0.03**
▪ Weaned calves vaccinated against *Campylobacter fetus* and/or *Leptospira* spp.		0.08	0.01	0.67	**0.02**

†*P*-value for Wald test of categorical variable; ††Unadjusted odds ratio

Table 3.6 Unconditional associations between calving month and vaccine use in Canadian cow-calf herds (n=131).

Vaccine use	Calving month	Odds Ratio[†]	Lower 95% CI	Upper 95% CI	*P*-value
Cows vaccinated against calf scours	Jan	(Ref)			**0.02**[††]
	Feb	0.95	0.28	3.28	0.94
	Mar	0.73	0.26	2.05	0.55
	Apr	0.24	0.08	0.69	**<0.01**
	May	0.05	0.01	0.48	**<0.01**
	Nov-Dec	0.60	0.13	2.71	0.50
Weaned calves vaccinated against BVDV	Jan	(Ref)			**<0.01**[††]
	Feb	0.19	0.05	0.66	**<0.01**
	Mar	0.17	0.06	0.50	**<0.01**
	Apr	0.58	0.19	1.81	0.35
	May	0.44	0.10	2.00	0.29
	Nov-Dec	0.36	0.08	1.74	0.21
Weaned calves vaccinated against IBR, BRSV, and PI3	Jan	(Ref)			**<0.01**[††]
	Feb	0.23	0.07	0.82	**0.02**
	Mar	0.15	0.05	0.44	**<0.01**
	Apr	0.68	0.22	2.15	0.51
	May	0.44	0.10	2.00	0.29
	Nov-Dec	0.58	0.12	2.95	0.51
Suckling calves vaccinated against IBR (<3 months of age with injectable product)	Jan	(Ref)			**<0.01**[††]
	Feb	3.30	0.98	11.1	0.05
	Mar	4.83	1.68	13.9	**<0.01**
	Apr	2.75	0.97	7.80	0.06
	May	0.53	0.09	2.94	0.46
	Nov-Dec	0.26	0.03	2.40	0.24

[†]Unconditional odds ratio; [††]*P*-value for Wald test of categorical variable

Table 3.7 Relative difference between Western and Eastern regions of Canada and vaccines used in cow-calf herds. Reported as proportion of herds (number of herds).

Administered ≥ 1 dose	Western herds (n=91)	Eastern herds (n=40)	OR[†]	95% CI	P-value
Bulls					
Any vaccine	0.82 (75)	0.85 (34)	0.83	0.30, 2.30	0.72
BVDV Type 1 or 2	0.73 (66)	0.80 (32)	1.24	0.28, 5.50	0.78
IBR, BRSV, PI3	0.73 (66)	0.80 (32)	1.24	0.28, 5.50	0.78
M. haemolytica +/- P. multocida	0.09 (8)	0.08 (3)	1.35	0.34, 5.46	0.67
H. somni	0.20 (18)	0.08 (3)	3.04	0.84, 11.0	0.09
Campylobacter and/or *Leptospira* spp.	0.27 (25)	0.35 (14)	0.82	0.35, 1.88	0.63
Clostridia spp.	0.57 (52)	0.33 (13)	2.77	1.27, 6.05	**0.01**
Footrot	0.44 (40)	0 (0)	--	--	**<0.01**
Cows					
Any vaccine	0.96 (87)	1.00 (40)			
BVDV Type 1 or 2	0.92 (84)	0.93 (37)	0.97	0.24, 3.97	0.97
IBR, BRSV, PI3	0.92 (84)	0.93 (37)	0.97	0.24, 3.97	0.97
M. haemolytica +/- P. multocida	0.01 (1)	0.10 (4)	0.10	0.01, 0.93	**0.04**
H. somni	0.22 (20)	0.10 (4)	2.54	0.81, 7.97	0.11
Campylobacter and/or *Leptospira* spp.	0.33 (30)	0.48 (19)	0.54	0.25, 1.16	0.12
Clostridia spp.	0.68 (62)	0.33 (13)	4.44	2.00, 9.83	**<0.01**
Calf scours	0.55 (50)	0.48 (19)	1.35	0.64, 2.84	0.43
Footrot	0.02 (2)	0 (0)	--	--	0.99
Replacement heifers					
Any vaccine	0.97 (88)	0.90 (36)	3.26	0.69, 15.3	0.13
BVDV Type 1 or 2	0.95 (86)	0.85 (34)	3.04	0.87, 10.6	0.08
IBR, BRSV, PI3	0.95 (86)	0.85 (34)	3.04	0.87, 10.6	0.08
M. haemolytica +/- P. multocida	0.05 (5)	0.13 (5)	0.41	0.11, 1.49	0.18
H. somni	0.26 (24)	0.13 (5)	2.51	0.88, 7.14	0.09
Campylobacter and/or *Leptospira* spp.	0.36 (33)	0.43 (17)	0.77	0.36, 1.64	0.50
Clostridia spp.	0.82 (75)	0.33 (13)	9.74	4.15, 22.9	**<0.01**
Calf scours	0.59 (54)	0.43 (17)	1.97	0.93, 4.20	0.08
Suckling calves					
Any vaccine	0.98 (89)	1.00 (40)	n/a		
BVDV Type 1 or 2	0.80 (73)	0.73 (29)	1.53	0.65, 3.65	0.33
IBR, BRSV, PI3	0.91 (83)	0.93 (37)	0.84	0.21, 3.35	0.81
IN IBR, BRSV, PI3	0.31 (28)	0.38 (15)	0.74	0.34, 1.62	0.45
M. haemolytica +/- P. multocida	0.67 (61)	0.30 (12)	4.74	2.12, 10.6	**<0.01**
H. somni	0.52 (47)	0.13 (5)	7.48	2.69, 20.8	**<0.01**
Clostridia spp.	0.95 (86)	0.70 (28)	7.37	2.39, 22.8	**<0.01**
Weaned calves					
Any vaccine	0.64 (58)	0.73 (29)	0.67	0.29, 1.51	0.33
BVDV Type 1 or 2	0.54 (49)	0.65 (26)	0.63	0.29, 1.36	0.24
IBR, BRSV, PI3	0.54 (49)	0.68 (27)	0.56	0.26, 1.22	0.15
M. haemolytica +/- P. multocida	0.35 (32)	0.18 (7)	2.56	1.02, 6.42	**0.05**
H. somni	0.18 (16)	0.13 (5)	1.49	0.51, 4.40	0.47
Clostridia spp.	0.33 (30)	0.15 (6)	2.79	1.05, 7.36	**0.04**

[†]Unadjusted odds ratio

Table 3.8 Summary of Canadian cow-calf producer's top three factors influencing their decisions around whole herd vaccination protocols and whether to vaccinate suckling calves (n=131).

Top three influential factors	Proportion of herds (n)
Whole herd vaccination protocols	
Importance of the disease in my herd	0.64 (84)
Economic benefits of using that vaccine in my herd	0.53 (69)
Potential to minimize treatment rate and antimicrobial use	0.52 (68)
Time of year the vaccine needs to be given	0.33 (43)
Whether the vaccine is modified live or killed/inactivated	0.31 (40)
Whether I must boost the vaccine (more than 1 dose needed)	0.21 (28)
Other (*Answers included: veterinarian's advice, sale protocol*)	0.18 (23)
Route of administration	0.13 (17)
Potential reactions or side effects of the vaccine	0.07 (9)
Vaccine cost	0.06 (8)
Whether I must mix the vaccine before use	0 (0)
Vaccination of suckling calves	
Convenience (calves were being handled for some other reason)	0.77 (101)
Need for adequate labour to handle and vaccinate the calves	0.63 (83)
History of calf health problems	0.41 (54)
Need for adequate handling facilities	0.31 (41)
Busy time of year	0.28 (37)
Challenge of separating cow from calf	0.14 (18)
Other (*Answers included: veterinary recommendation, sale protocol, age of calf, location of cow herd from home, calves born on pasture, weather*)	0.14 (18)
Uncertainty about vaccine effectiveness	0.06 (8)
Cost of the vaccine	0.05 (7)

Table 3.9 Associations ($p<0.20$) between vaccination status and calf mortality, calf morbidity, and nonpregnant breeding females (n=124).

Reported using vaccine: yes vs no	Odds Ratio†	Lower 95% CI	Upper 95% CI	P-value
Calf mortality				
Heifers vaccinated against:				
Calf scours	0.80	0.61	1.05	0.10
Suckling calves vaccinated against:				
Clostridial disease	0.65	0.43	0.97	**0.03**
Calf morbidity due to pneumonia				
Suckling calves vaccinated against:				
BVDV types 1 and 2	2.02	1.17	3.47	**0.01**
M. haemolytica +/- *P. multocida*	2.31	1.32	4.07	**<0.01**
H. somni	1.59	0.94	2.70	0.08
Any target	2.16	0.88	5.29	0.09
Calf morbidity due to calf scours				
Suckling calves vaccinated against:				
Any target	0.29	0.07	1.30	0.11
Non-pregnancy in breeding females				
Cows vaccinated against:				
Campylobacter fetus or *Leptospira* spp.	1.22	0.98	1.52	0.07
Heifers vaccinated against:				
BVDV, IBR, BRSV, and PI3	1.33	0.99	1.78	0.06

†Odds ratio adjusted for cow herd size, calving month and geographical location

3.9 Figures

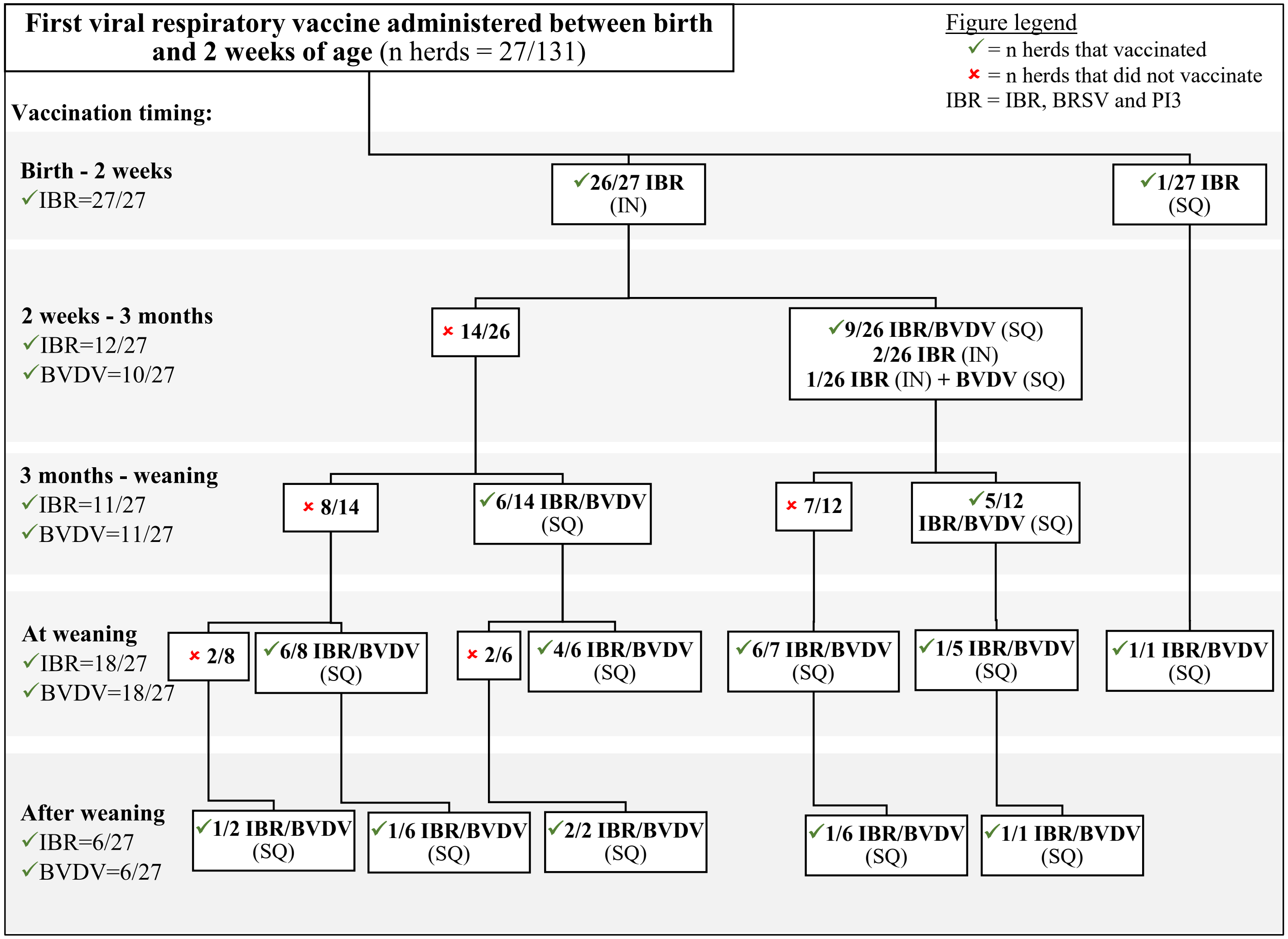

Figure 3.1 Vaccination protocols of Canadian cow-calf producers who first vaccinated calves against IBR between birth and 2 weeks of age.

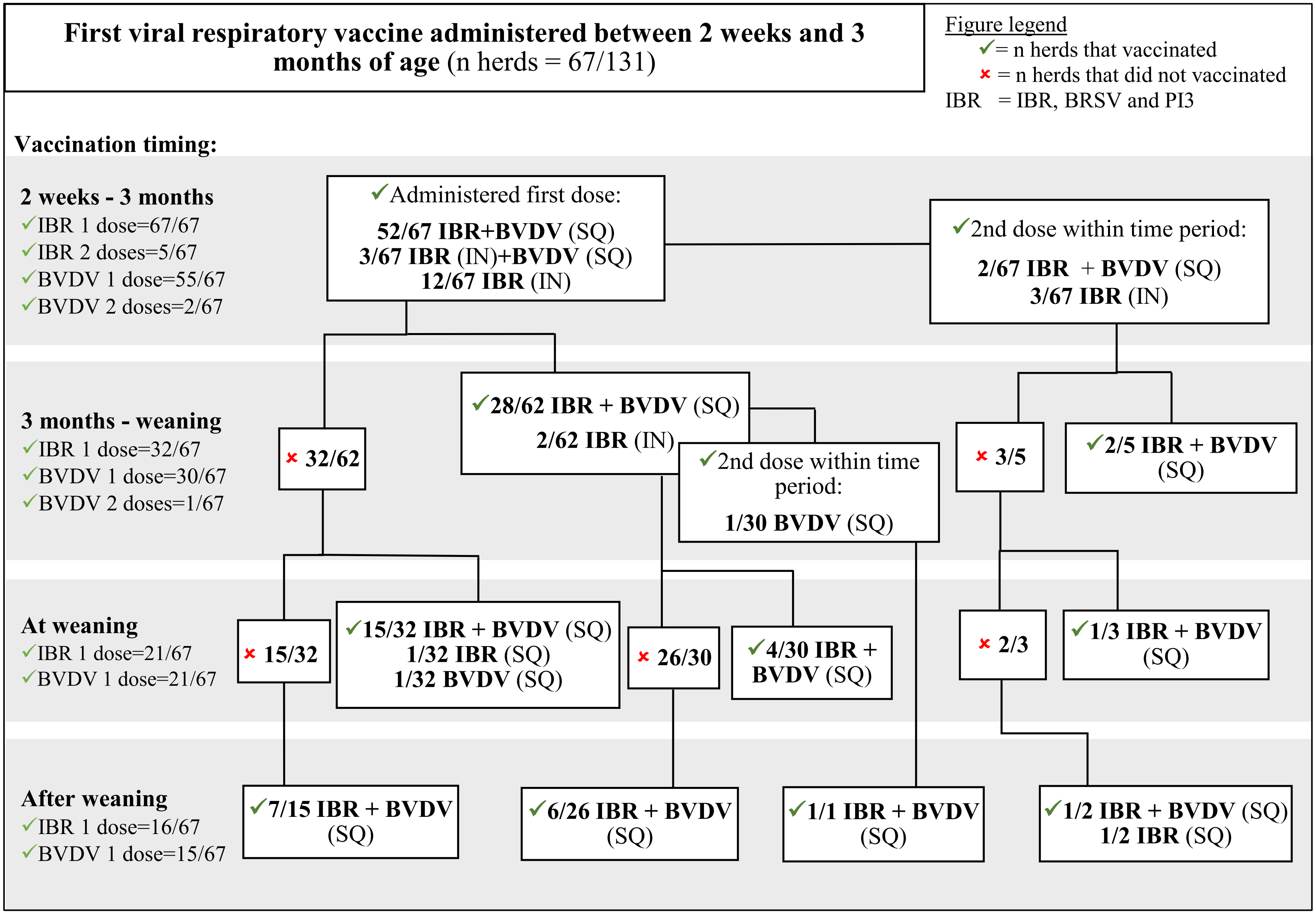

Figure 3.2 Vaccination protocols of Canadian cow-calf producers who first vaccinated calves against IBR between 2 weeks and 3 months of age.

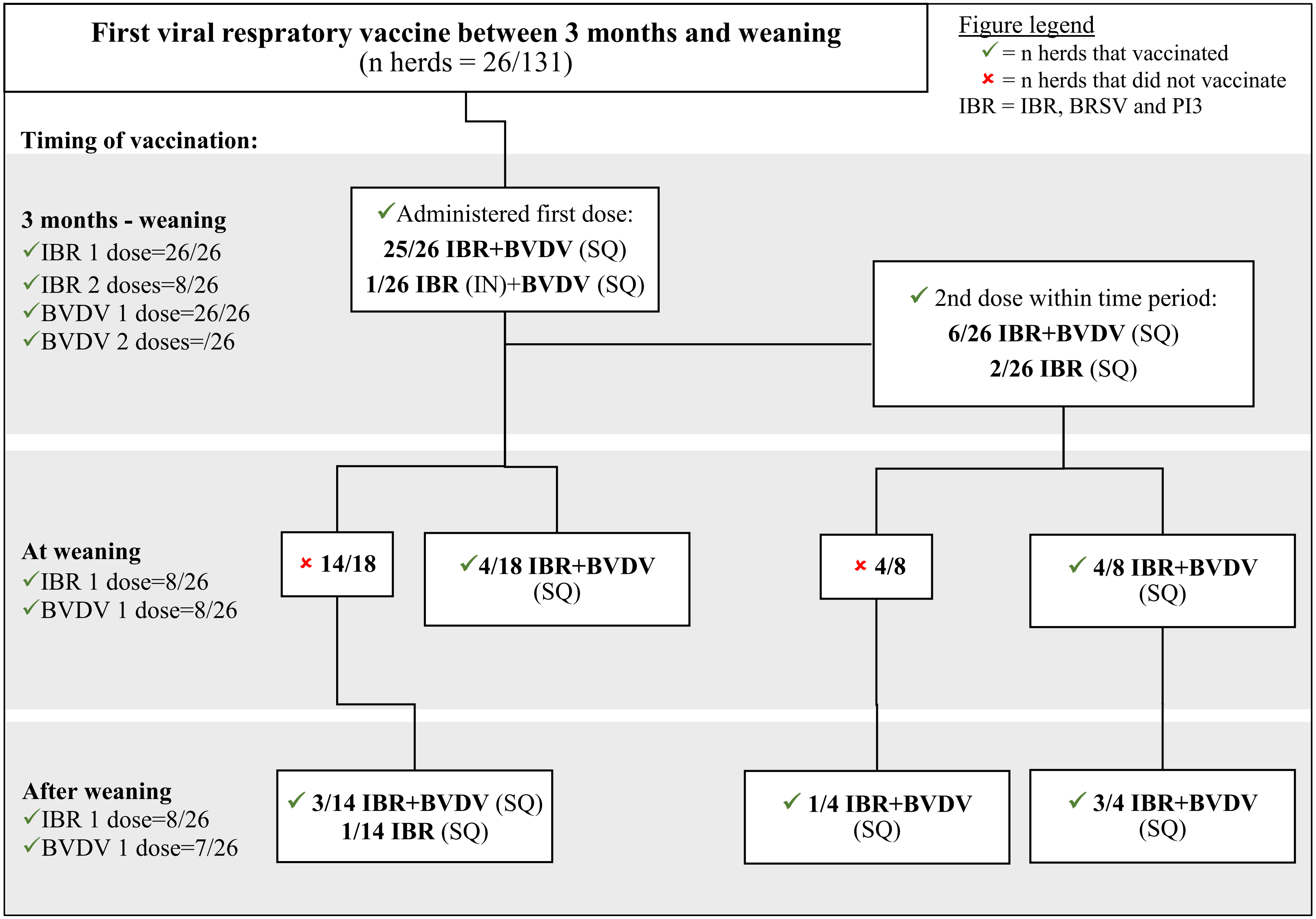

Figure 3.3 Vaccination protocols of Canadian cow-calf producers who first vaccinated calves against IBR between 3 months of age and weaning.

CHAPTER 4: GENERAL DISCUSSION AND CONCLUSION

4.1 Introduction and objectives

Understanding technologies and management practices used by Canadian cow-calf producers is necessary to identify areas for growth and improvement. There are numerous technologies available that help to increase labour efficiency, growth, reproduction, feed, and economic efficiency in cow-calf herds (1-8). Improvement in uptake of technologies such as vaccine use is vital to reduce the use of antimicrobials on the ranch and in the feedlot; potentially reducing the prevalence of antimicrobial resistant pathogens that pose a serious threat to the long term economic and environmental sustainability of the Canadian beef industry (9-12). Previous regional surveys had attempted to gather similar information but lack of uniformity amongst data collected makes comparison between regions and interpretation difficult (13-16).

The objectives of this study were to describe technology adoption, record keeping practices, and vaccine use in Canadian cow-calf herds, assess associations between herd attributes, productivity outcomes and adoption, and identify opportunities for improvement.

4.2 Key findings

In Chapter 2, survey data was collected and analyzed from 131 (131/162, 81%) cow calf producers across Canada (91 western herds, 40 eastern herds). Key data investigated was the frequency of use and adoption of available technologies, and record keeping practices utilized by producers. Unconditional univariable regression was used to assess associations between technology adoption and record keeping practices, and herd or producer attributes. Multivariable regression was conducted to assess associations between use of herd management practices and technologies, and productivity outcomes including calf morbidity and mortality, and frequency of non-pregnant breeding females.

The most common technologies reported as "currently in use" were individual female production records (69%), feed or forage testing (61%), and use of an on-farm animal weigh scale (56%). The term "individual female production records" was not defined in the survey and therefore may encompass any record types maintained for individual cows. The use of a scale to measure individual animal weaning weights is an important area for improvement, as this is a key measurement to determine individual animal and herd level productivity. Alternatively, telemetry devices, drones, and sexed semen, were reported as "never used" by 95%, 86%, and 85% of producers respectively. The main reasons reported by producers for the maintenance of producer records were for culling decisions (84%) and replacement heifer selection (82%). The use of both feed and water testing has increased in western herds since previous reports of the same region (15). Depending on the production system and operation needs, remote monitoring technologies including drones and cameras can provide a great opportunity for producers to reduce labour and associated costs, while increasing individual animal and fence-line monitoring (17-19), however less than half of producers currently utilize these technologies. Herd and producer attributes associated with adoption of technology and record keeping practices included herd size, calving location, cattle type (commercial vs purebred), herd location, producers who retained calves post-weaning, and producer education level. After accounting for herd size and calving month, calf mortality was higher in herds where financial records were analyzed by the producer rather than an accountant and higher in herds where water testing was not utilized. In this case, water testing and the use of an accountant is representative of a more precise and thorough management style. The association between the use of reproductive technologies and increased risk of poor calf health outcomes has been documented as is likely associated with the increased handling, stress and opportunities for disease transmission among calves (20-22). The risk of treating calves for pneumonia or calf scours was lower in herds that implemented feed and water related technologies, compared to those that did not. This may be indicative of overall herd management but it is also known that dry cow nutrition plays an important role in colostrum quality which directly impacts calf health outcomes (23, 24).

In Chapter 3, vaccination protocols and factors associated with vaccine use in Canadian cow-calf herds were described. Herd management surveys (n=131) from producers recruited through a national cow-calf surveillance program, were analyzed. Vaccination protocols were determined by animal type (i.e., bulls, cows, replacement heifers, weaned calves, and suckling calves). Descriptive statistics were used to determine overall vaccine use and product administration timing. Unconditional, univariable logistic regression was utilized to determine vaccine use predictors including producer and herd attributes. Multivariable analysis was conducted to determine associations between vaccine use and productivity outcomes including calf morbidity and mortality, and occurrence of non-pregnant breeding females.

Vaccine use has increased or remained constant across the country since previous regional surveys (13-16). The most common vaccine targets administered to bulls, cows and replacement heifers were IBR, BRSV, PI3, BVDV and clostridial vaccines, followed by calf scours vaccines in cows and replacement heifers. While most producers vaccinated their animals, an important percentage of herds have not yet implemented a vaccine protocol that includes all core vaccines. Vaccination of bulls has increased in both eastern and western Canada since previous reports (8, 14), but use of clostridial vaccines is low despite its status as a core vaccine (25). Mature breeding cattle were most often administered viral vaccines in MLV form prior to breeding. Canadian and American bovine veterinarians recommend vaccinating bulls and cows at the same time (26). Clostridial vaccines, though common in both, were more commonly used in replacement heifers than cows. The only vaccine commonly administered to mature breeding females prior to calving was for calf scours.

Vaccination of all calves has increased since previous surveys of western Canada and northern Ontario and Quebec (8, 16) but vaccination of weaned calves is less common (66%) compared to suckling calves (98%). Common vaccines administered to suckling calves included IBR/BRSV/PI3 (92%), clostridial (87%) and BVDV (78%) vaccines. The same targets were common in weaned calves with the exception of clostridial vaccines. Similar to previous western Canadian reports (8), viral vaccines administered to calves were almost exclusively MLV, as is the recommendation of most beef cattle veterinarians (26). Suckling calves were mainly vaccinated between 2 weeks of age and weaning for all targets, but 26/27 herds that were administered viral respiratory vaccines prior to 2 weeks of age received intranasal vaccines; use of intranasal vaccines near birth has increased since previous regional reports (8, 13, 14). Most calves (67%, 18/27) that received an IBR/BRSV/PI3 vaccine prior to 2 weeks of age received a second dose prior to weaning, but these calves were less likely to receive 2 doses of BVDV vaccine prior to weaning compared to calves first vaccinated after 2 weeks of age. While administration of one clostridial vaccine was common (87%) in suckling calves, few herds were administered a booster prior to weaning (26%); most commercial vaccines in Canada require a second dose. Regional differences were scarce apart from clostridial vaccine use which as lower in eastern Canada; though the risk is present across the country. Vaccine use was found to be associated with herd and producer attributes. Generally, producers with small herds (<100 cows) were less likely to vaccinate cattle compared to larger herds (>100 cows). Producers who retained calves post-weaning were more likely to vaccinate weaned calves for IBR, BRSV, PI3, BVSV, and *M. haemolytica*, and vaccine heifers against IBR, BRSV, PI3 and BVDV. Owning purebred cattle was a positive predictor for vaccination of weaned calves against BVDV and bacterial reproductive pathogens. Calving month was associated with viral respiratory vaccine use in calves and calf scours vaccines in cows. Producers reported the largest motivator for vaccinating cattle was the "importance of disease in the herd". Similar to previous studies, the risk of pneumonia was higher in herds where suckling calves were vaccinated against BVDV and bacterial respiratory pathogens, compared to those that were not; given producers' motivation for vaccinating, the use of these vaccines is likely in response to disease challenges faced by the herd rather than the disease being a consequence of the vaccine (3). Suckling calves administered clostridial vaccines were at lower risk of mortality, which may demonstrate vaccine efficacy or be an indicator of overall herd management.

4.3 Research limitations

The limitations identified in this study provide considerations for future observational research in the cow-calf industry. The study population was limited to herds that were part of the C3SN which requires a breeding herd size of ≥ 40 animals, maintenance of calving records, routine pregnancy testing, and access to email. Because herds were recruited through veterinarians, it was an unofficial requirement for herds to have regular contact with a veterinarian. Selection bias is possible when using non-random selection and these herds may not be representative of all Canadian cow-calf herds but rather a progressive subset of cow-calf producers in Canada, due to the strict enrollment criteria. This cohort likely represents "early adopters" of innovative practices. This knowledge is useful in understanding the opportunity for growth in technology and vaccine adoption in Canada. While the use of census data creates less opportunity for selection bias, survey data allows for collection of similar or more specific data at a lower cost (27). Comparison to census data where possible could show if this subset of herds is representative. Another way to mitigate selection bias would be to create a more open call for producers interested in participating, reducing size and management practice limitations. However, given the progressive nature of producers willing to participate and provide the requested information and documents, surveys such as this will likely always have some level of selection bias. To limit the possibility of information bias, this survey tool was tested on a subset of the population prior to use for this study, following recommended protocols (27). To mitigate recall bias that can occur with observational studies, producers were provided coloured vaccine produce manuals to assist in correctly identifying specific vaccine products used.

The years in which data and surveys were collected were impacted by adverse environmental, social, and economic events (COVID19 and drought) that may have altered producers' normal behaviours and decisions during those years. This may include limiting spending in certain areas and management decisions to mitigate temporally unique business and feed related challenges.

4.4 Future research opportunities

Due to changing expectations of the beef industry as a result of environmental challenges, animal health and welfare concerns, and economic pressures, the need for information regarding management practices and technological uptake is needed. Opportunities for future research include development of more broadly accepted and recommended viral respiratory vaccine protocols for calves between birth and weaning. This thesis identified the extremely wide range of vaccine types and protocols used in suckling calves, showcasing a clear absence of uniform veterinary recommendations. While all herds have different vaccination requirements, the lack of knowledge surrounding the optimal first vaccination timing, type (MLV or inactivated, IN or

SQ) of subsequent doses, and relative efficiency of vaccinating neonatal calves to prepare calves immune systems for periods of high disease challenge and stress creates challenges for both producers and veterinarians.

There is also an opportunity to gain more data on the labour and economic impacts of adopting new technologies, specifically remote monitoring technologies and electronic data management software. Research on how these tools can be made affordable for smaller cow-calf operations is essential. Herd size cannot be the limitation for technological uptake because this will prevent small herd from remaining competitive and viable in the Canadian cow-calf industry.

Future research could focus on the creation and implementation of more robust preconditioning programs. While many producers vaccinate calves, there are few economic incentives in Canada to ensure calves are fully and properly vaccinated prior to feedlot placement. The result of this is felt heavily in the high levels of disease and antimicrobial resistance in feedlot cattle.

4.5 Conclusions

The results of this study showcase the impressive level of innovation, progress, and motivation of Canadian cow-calf producers to create a more efficient and sustainable beef industry. Technology adoption is a critical component in maintaining animal health and welfare standards, and environmental stewardship through efficient production practices that have become increasingly expected and necessary in modern beef production.

Technology adoption has increased or remained steady over time, and the depth of progress reflects that. While reproductive technologies were utilized, the focus of most cow-calf producers was on technologies to increase animal growth and feed efficiency. Maintenance of individual female production records was the most adopted technology. There remains room for improvement in the use of electronic devices and software to store and analyze production records. Additionally, Eastern Canada has room for improvement in the utilization of feed testing and nutritionists to ensure optimal animal nutrition, reduce feed waste and evaluate costs. Vaccine use as a technology to reduce disease and the associated economic burdens has increased across Canada over the past few decades. Positive changes have occurred including the increased use of intranasal respiratory vaccines in neonatal calves and increased focus on respiratory disease vaccines. While producers generally vaccinated according to recommended core vaccine guidelines, opportunities to improve exist. This includes proper administration and timing of vaccine doses according to product label instructions. Early vaccination of calves provides producers more time to administer a second dose, where applicable, prior to weaning and calves leaving the ranch.

While the benefits of technologies and vaccines are known, the necessity of use is unique for each individual herd. This study has showcased the diversity of cow-calf operations across Canada. Technological needs, primary production focus, and opportunities for improvement vary depending on operation and producer attributes. The primary industry focuses should be on increasing economic incentives for producers to vaccinate calves fully prior to weaning and understand the unique technological needs of different types of cow-calf operations.

4.6 References

1. Jelinski M, Bergen R, Grant B, and Waldner C. Adoption of technology and management practices by Canadian cow-calf producers. Can Vet J 2019;60 (3): 287-293.

2. Pearson JM, Pajor EA, Caulkett NA, Levy M, Campbell JR, and Windeyer MC. Benchmarking calving management practices on western Canada cow-calf operations. Transl Anim Sci 2019;3 (4): 1446-1459.

3. Waldner CL, Wilhelm B, Windeyer MC, Parker S, and Campbell J. Improving beef calf health: frequency of disease syndromes, uptake of management practices following calving, and potential for antimicrobial use reduction in western Canadian herds. Transl Anim Sci 2022;6 (4): txac151.

4. Manglai. Examining Record Keeping and Benchmarking Effects on the Production and Performance of Cow-calf Farms in Canada Saskatoon: University of Saskatchewan, 2016.

5. Waldner C, Jelinski M, and McIntyre-Zimmer K. Survey of western Canadian beef producers regarding calf-hood diseases, management practices, and veterinary service usage. Can Vet J 2013;54: 599-564.

6. Waldner C. Cow attributes, herd management, and reproductive history events associated with abortion in cow-calf herds from Western Canada. Theriogenology 2014;81 (6): 840-848.

7. Waldner CL and Garcia Guerra A. Cow attributes, herd management, and reproductive history events associated with the risk of nonpregnancy in cow-calf herds in Western Canada. Theriogenology 2013;79 (7): 1083-1094.

8. Waldner CL, Parker S, and Campbell JR. Vaccine usage in western Canadian cow-calf herds. Can Vet J 2019;60 (4): 414-422.

9. Waldner CL, Parker S, Gow S, Wilson DJ, and Campbell JR. Antimicrobial usage in western Canadian cow-calf herds. Can Vet J 2019;60 (3): 255-267.

10. Hilton WM. BRD in 2014: where have we been, where are we now, and where do we want to go? Anim Health Res Rev 2014;15 (2): 120-122.

11. USDA NAHMS. Feedlot 2011 Part IV: Health and health management, 2013.

12. Brault SA, Hannon SJ, Gow SP, et al. Antimicrobial Use on 36 Beef Feedlots in Western Canada: 2008–2012. Front Vet Sci 2019;6.

13. Maritime Beef Council. Atlantic Cow-Calf Production Survey Aggregate Results, 2018.

14. Ontario Cow-Calf 2015/16 Production Survey (OCC). OCC: University of Guelph. 2018. Available from https://www.beefresearch.ca/files/pdf/Ontario%20Cow-Calf%20Summary%20Nov%2012%202018.pdf.

15. "Western Canadian Cow-Calf Survey II". WCCCSN. University of Saskatchewan. Available from http://westernbeef.org/pdfs/wcccs/WCdnSurveyII_FINAL.pdf.

16. Lamothe S and North Haven Solutions. Northern beef study: Northern Ontario and Northern Quebec beef cow-calf production. 2018.

17. Using Drones to Monitor Fence Lines: AEN-159. Jackson J: University of Kentucky Agricultural Communications Service. Available from http://www2.ca.uky.edu/agcomm/pubs/AEN/AEN159/AEN159.pdf.

18. Liu C, Jian Z, Xie M, and Cheng I. A Real-Time Mobile Application for Cattle Tracking using Video Captured from a Drone. International Symposium on Networks, Computers and Communications (ISNCC) Year: 1-6.

19. Hoagg J, Jackson J, Sama M, and Yang R. NRI: INT: Autonomous unmanned aerial robots for livestock health monitoring. 2020 National Robotics Initiative Principal Investigators Meeting Year

20. Waldner C, Wilhelm B, Windeyer MC, Parker S, and Campbell J. Improving beef calf health: frequency of disease syndromes, uptake of management practices following calving, and potential for antimicrobial use reduction in western Canadian herds. Transl Anim Sci 2022;6 (4): txac151.

21. Woolums AR, Berghaus RD, Smith DR, et al. Producer survey of herd-level risk factors for nursing beef calf respiratory disease. JAVMA 2013;243 (4): 538-547.

22. Wennekamp TR, Waldner CL, Parker S, Windeyer MC, Larson K, and Campbell JR. Biosecurity practices in western Canadian cow-calf herds and their association with animal health. Can Vet J 2021;62 (7): 712-718.

23. Waldner CL and Rosengren LB. Factors associated with serum immunoglobulin levels in beef calves from Alberta and Saskatchewan and association between passive transfer and health outcomes. Can Vet J 2009;50 (3): 275-281.

24. Pecka-Kiełb E, Zachwieja A, Wojtas E, and Zawadzki W. Influence of nutrition on the quality of colostrum and milk of ruminants. Mljekarstvo 2018;68 (3): 169-181.

25. AABP Vaccination Guidelines. American Association of Bovine Practitioners. Ashland, OH. Available from http://www.aabp.org/committees/resources/VaccGuidelines2021.pdf.

26. Fike GD, Simroth JC, Thomson DU, Schwandt EF, Spare R, and Tarpoff AJ. A survey of recommended practices made by veterinary practitioners to cow-calf operations in the United States and Canada. Prof Anim Sci 2017;33 (6): 716-728.

27. Dohoo I, Martin W, and H. S. Veterinary Epidemiologic Research. 2nd ed: VER Inc., 2009.

APPENDIX A

Table A1 Technology adoption in western and eastern Canadian cow-calf herds.

Technology/Practice	Western herds (n=91)				Eastern herds (n=40)				P-value: Current use western vs eastern herds
	Current use	Occasional use	Previous use	Never used	Current use	Occasional use	Previous used	Never used	
Individual female production records	0.69 (63)	0.11 (10)	0.07 (6)	0.12 (11)	0.70 (28)	0.10 (4)	0.05 (2)	0.15 (6)	0.93
Forage/feed quality testing	**0.73 (66)**	0.21 (19)	0.02 (2)	0.04 (4)	**0.35 (14)**	0.28 (11)	0.20 (8)	0.15 (6)	**0.001**
On farm scale for weighing animals	0.56 (51)	0.09 (8)	0.04 (4)	0.30 (27)	0.55 (22)	0.13 (5)	0 (0)	0.33 (13)	0.91
Defined breeding season of ≤ 63 days	0.51 (46)	0.20 (18)	0.08 (7)	0.23 (21)	0.33 (13)	0.15 (6)	0.05 (2)	0.48 (19)	0.06
Cameras/ remote monitoring technologies	0.45 (41)	0.04 (4)	0.01 (1)	0.49 (45)	0.33 (13)	0 (0)	0.05 (2)	0.63 (25)	0.18
RFID tag scanner	0.43 (39)	0.03 (3)	0.10 (9)	0.45 (41)	0.28 (11)	0.10 (4)	0.05 (2)	0.58 (23)	0.10
Use of nutritionist	**0.46 (42)**	0.25 (23)	0.08 (7)	0.21 (19)	**0.15 (6)**	0.43 (17)	0.08 (3)	0.35 (14)	**0.001**
Growth promoting ear implant in suckling calves	**0.41 (37)**	0.02 (2)	0.15 (14)	0.42 (38)	**0.10 (4)**	0 (0)	0.10 (4)	0.80 (32)	**0.001**
Artificial insemination (heifers)	0.24 (22)	0.05 (5)	0.26 (24)	0.43 (39)	0.38 (15)	0.20 (8)	0.18 (7)	0.23 (9)	0.12
Ionophores in breeding cows	**0.35 (32)**	0.11 (10)	0.18 (16)	0.35 (32)	**0.08 (3)**	0.05 (2)	0.13 (5)	0.70 (28)	**0.001**
Artificial insemination (cows)	**0.19 (17)**	0.08 (7)	0.21 (19)	0.53 (48)	**0.43 (17)**	0.20 (8)	0.10 (4)	0.28 (11)	**0.004**
Parentage testing	0.21 (19)	0.08 (7)	0.03 (3)	0.67 (61)	0.23 (9)	0.18 (7)	0.03 (1)	0.58 (23)	0.84
Growth promoting ear implant in weaned calves	**0.24 (22)**	0.05 (5)	0.12 (11)	0.57 (52)	**0.05 (2)**	0 (0)	0.13 (5)	0.83 (33)	**0.009**
Water testing	0.20 (18)	0.24 (22)	0.27 (25)	0.27 (25)	0.13 (5)	0.23 (9)	0.20 (8)	0.45 (18)	0.31
Genetic Testing	0.16 (15)	0.02 (2)	0.04 (4)	0.76 (69)	0.20 (8)	0.15 (6)	0.03 (1)	0.63 (25)	0.63
Ionophores in suckling calves	0.16 (15)	0.10 (9)	0.08 (7)	0.64 (58)	0.18 (7)	0.08 (3)	0.10 (4)	0.65 (26)	0.89
Heat/Estrus sync. (heifers)	0.12 (11)	0.12 (11)	0.31 (28)	0.45 (41)	0.20 (8)	0.23 (9)	0.28 (11)	0.30 (12)	0.24
Heat/Estrus sync. (cows)	0.14 (13)	0.05 (5)	0.20 (18)	0.59 (54)	0.15 (6)	0.25 (10)	0.20 (8)	0.40 (16)	0.92
Remote water monitoring system	0.20 (18)	0.05 (5)	0.02 (2)	0.73 (66)	0.08 (3)	0 (0)	0 (0)	0.90 (36)	0.08
Embryo transfer	0.12 (11)	0.01 (1)	0.11 (10)	0.74 (67)	0.13 (5)	0.08 (3)	0.08 (3)	0.73 (29)	0.95
Drones	0.10 (9)	0.04 (4)	0.02 (2)	0.82 (75)	0.05 (2)	0 (0)	0 (0)	0.95 (38)	0.35
Sexed semen	0.02 (2)	0.03 (3)	0.08 (7)	0.87 (79)	0.08 (3)	0.05 (2)	0.08 (3)	0.80 (32)	0.15
Telemetry devices	0 (0)	0 (0)	0.04 (4)	0.95 (86)	0 (0)	0 (0)	0 (0)	0.95 (38)	0.99

Table A2 Data included in production records of western and eastern Canadian cow-calf producers. Reported as proportion (number) of herds.

	West (n=91)	East (n=40)
Feeding management and pasture use records		
Pasture use/ grazing management	0.75 (68)	0.70 (28)
Mineral purchases and use	0.69 (63)	0.68 (27)
Forage production	0.57 (52)	0.65 (26)
Feed purchases	0.47 (43)	0.45 (18)
Winter feeding details	0.48 (44)	0.33 (13)
Breeding management records		
Bull turnout and pull dates	0.97 (88)	0.98 (39)
Pregnancy testing records	0.89 (81)	0.90 (36)
Bull testing records	0.92 (84)	0.38 (15)
Calving and weaning records		
Calf sex	0.97 (88)	1.00 (40)
Birth date	0.96 (87)	1.00 (40)
Calving assistance	0.96 (87)	0.98 (39)
Calf's ID linked to dam ID	0.91 (83)	0.98 (39)
Cow health problems at calving	0.88 (80)	0.83 (33)
Weaning date	0.71 (65)	0.73 (29)
Birth weight	0.46 (42)	0.75 (30)
Individual weaning weight	0.41 (37)	0.55 (22)
Animal health records		
Vaccines	0.90 (82)	0.93 (37)
Death loss	0.90 (82)	0.78 (31)
Antibiotics	0.87 (79)	0.80 (32)
Culling	0.88 (80)	0.75 (30)
Individual animal health records	0.86 (78)	0.73 (29)
Parasite control	0.80 (73)	0.83 (33)
Pain control/NSAIDS	0.77 (70)	0.65 (26)
Herd level treatment records		
Date of treatment	0.82 (75)	0.85 (34)
Name of product administered	0.78 (71)	0.85 (34)
Identity of group treated	0.70 (64)	0.73 (29)
Number of animals treated	0.59 (54)	0.60 (24)
Dosage	0.55 (50)	0.53 (21)
Diagnosis or treatment reason	0.51 (46)	0.45 (18)
Injection or administration location	0.47 (43)	0.43 (17)
Other *(Answers: withdrawal time, product lot #)*	0.12 (11)	0.10 (4)
Did not maintain herd level treatment records	0.16 (15)	0.10 (4)
Individual animal treatment records included:		
Date of treatment	0.93 (85)	0.90 (36)
Animal ID	0.92 (84)	0.90 (36)
Name of product administered	0.90 (82)	0.83 (33)
Diagnosis or treatment reason	0.82 (75)	0.75 (30)
Dosage	0.78 (71)	0.70 (28)
Injection or administration location	0.57 (52)	0.43 (17)
Other *(Answers: withdrawal time, animal weight, animal temperature, administration site/method, product lot #)*	0.13 (12)	0.08 (3)
Did not maintain individual animal treatment records	0.08 (7)	0.10 (4)