VETERINARY MEDICINE
MASTER THESIS

CURRENT SELECTIVE PRACTICES FOR DRY COW THERAPY AND CLINICAL MASTITIS TREATMENT ON CANADIAN DAIRY FARMS

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ABSTRACT

The objective of this study was to gain insight into selective practices for dry cow therapy (DCT) and clinical mastitis (CM) treatment on Canadian dairy farms, as limited information is available in the literature regarding these practices in Canada. A structured questionnaire was completed by 146 dairy producers from five Canadian regions, as part of the Canadian Dairy Network for Antimicrobial Stewardship and Resistance (CaDNetASR) initiative.

Selecting CM cases to treat with antimicrobials was done by 60% of producers compared to blanket treating all cases. Only 41% of producers selecting cases used somatic cell count (SCC) thresholds as criteria, with 200,000 - 300,000 cells/mL used most frequently (55%). Furthermore, symptom severity was considered ‘important’ or ‘very important’ by the vast majority of producers (94%) when deciding on CM treatment. No associations were detected between use of selective CM therapy and province, housing, milking system or herd size.

Blanket DCT (BDCT) was more commonly practiced (65% of producers) compared to selective DCT (SDCT). Furthermore, no associations were detected between type of DCT and herd size, housing, milking system or province. SCC thresholds were frequently used as DCT selection criteria, with 150,000 - 200,000 cells/mL being the most frequently used as cut-off (63%). Information on past CM cases was used to select for DCT by 75% of producers practicing SDCT.

Internal teat sealant was administered to all cattle at dry-off by 59% of producers, more frequently in farms with parlour milking systems compared to pipeline ($P = 0.04$). Additionally, producers using teat sealant had a higher mean adult cow herd size (155) than producers not using teat sealant (118; $P = 0.03$). Written treatment protocols for DCT were available at only 29% of farms, whereas treatment protocols for mastitis were available at 50% of farms. In conclusion, there is potential to increase adoption of SDCT and selective CM treatment, which could reduce on-farm AMU.

INTRODUCTION

Both human and veterinary medicine are impacted by increased prevalence of antimicrobial resistance (AMR) bacteria (Zecconi et al., 2019) which develops when bacteria adapt and grow in the presence of antimicrobials they were previously susceptible to (WHO, 2015). In addition to general antimicrobial use (AMU), sub-optimal, misuse and overuse of antimicrobials, are of concern regarding the development of AMR bacterial populations (Gelband et al., 2015). AMR has been identified as a global risk with high social and economic impacts such as decreased national income and higher healthcare costs (Holmes et al., 2015). The continued development of AMR in humans is concerning as some of the most common diseases, such as bacterial pneumonia, cannot always be cured (WHO, 2015). In animals, AMR can lead to increased morbidity, mortality and decreased animal welfare (Laxminarayan et al., 2015; Wall et al., 2016). The connection between AMR and AMU in the dairy sector is worrisome (Cameron et al., 2014), and, therefore, pressure is increasing to reduce on-farm AMU (Swinkels et al., 2015).

In the 1960s, the potential for AMR transmission from animals to humans was recognised (Anderson and Lewis, 1965), and the relationship between AMU in veterinary medicine and human consequences was further described by Holmes et al. (2015). Bacteria, conferring AMR, can infect or colonize humans in many different ways. Transmission of AMR bacteria from animals to humans can occur by livestock product consumption, exposure to contaminated animal faeces, or through run-offs into groundwater and the environment, among other mechanisms (Kruse and Sorum, 1994; WHO, 2015; Laxminarayan et al., 2015). Farm workers have a higher risk of AMR bacterial infection, due to close contact with livestock potentially infected with AMR bacteria (WHO, 2015). Improving AMU stewardship in both human and veterinary medicine is therefore essential in limiting the development of AMR worldwide.

Clinical mastitis (CM) is an inflammation of the udder caused most commonly by bacteria, which is why antimicrobials are frequently used for treatment (Swinkels et al., 2015). Most AMU on dairy farms is therefore to treat and prevent mastitis (Neave et al., 1966; Scherpenzeel et al., 2016a; Lhermie et al., 2018). However, treating all CM cases with antimicrobials (blanket CM treatment) results in unnecessary and inappropriate AMU (Roberson, 2012). Many CM causing pathogens can be eliminated by the cow's immune response, or have non-bacterial causes meaning antimicrobials are not necessary or would not be effective (Kayitsinga et al., 2017). Furthermore, CM treatment is mostly unsupervised by veterinarians, and many treatments are considered extra-label (Oliveira and Ruegg, 2014).

In Canada, systemic administration of antimicrobials (SYA) contributes most to dairy farm AMU, followed by intramammary administration of antimicrobials (IMA) (Saini et al., 2012). However, proportions of SYA and IMA applied specifically for CM treatment were not described. Strategies like using on-farm bacterial culture (Lago et al., 2011) and grading mastitis severity (Roberson, 2012) as selection criteria could significantly reduce AMU in CM treatment. However, selective CM treatment practices have not been well described in literature (Oliveira and Ruegg, 2014).

To cure existing intramammary infections (IMI) and prevent future mastitis cases, IMA is often administered as dry cow therapy (DCT) (Cameron et al., 2014; Lhermie et al., 2018). Blanket DCT (BDCT) specifically refers to treating all cows with antimicrobials at dry off. BDCT is part of the “5-point plan” to control contagious mastitis and to reduce the prevalence of infectious IMI (Neave et al., 1966). However, due to reduction of bulk milk somatic cell count (SCC) and prevalence of IMI (Cameron et al., 2014), practicing BDCT may no longer be required on every farm. Therefore, reducing AMU can be achieved by selecting only those cows with IMI, or cows at risk of acquiring IMI during the dry period. This is referred to as selective DCT (SDCT) and aims to identify only those cows who would benefit from IMA at dry off (Lhermie et al., 2018). In addition, non-antimicrobial internal teat sealant is frequently used as part of SDCT. Teat sealants provide a physical barrier preventing bacteria from entering the teat (USDA, 2016), and they have been demonstrated to be effective in preventing new mastitis cases during the dry cow period (Huxley et al., 2002; Cameron et al., 2014; Dufour et al., 2019). However, the uptake of teat sealant use in Canada is unknown.

To understand current practices and highlight areas for intervention, monitoring livestock-associated AMU should be done regularly (Schukken et al., 2003). Several countries already monitor AMU in farm animals, like the Netherlands, the United Kingdom, Denmark, France and Canada, among others (SDa, 2018; DANMAP et al., 2018; UK-VARSS et al., 2019; RESAPATH, 2019), personal communication with Prof. Dr. Herman Barkema). In Germany and the Netherlands, preventive AMU on dairy farms has been forbidden since 2010 (Swinkels et al., 2015). This resulted in adjusting common treatments, such as no longer using IMA in every cow at dry-off (Scherpenzeel et al., 2014; Barkema et al., 2015) and changing antimicrobial dosage in CM treatment protocols (Swinkels et al., 2015).

In Canada, the ‘Canadian Dairy Network of Antimicrobial Stewardship and Resistance’ (CaDNetASR) started monitoring AMU and AMR patterns on 150 dairy farms in five regions in

2019. CaDNetASR aims to provide a benchmark to measure the effect of AMU reduction practices on the emergence and the spread of AMR bacteria in dairy cattle. As little information is available about on-farm DCT and CM treatment practices in Canada, the present study analyses part of collected CaDNetASR data to gain insight into selective practices for DCT and CM treatments.

MATERIALS AND METHODS

Data were collected using a questionnaire on 146 dairy farms in British Columbia, Alberta, Ontario, Quebec and Nova Scotia between July 2019 and December 2019. The questionnaire is attached (Appendix 1), and was regarding DCT and CM treatment practices, as part of the Canadian Dairy Network for Antimicrobial Stewardship and Resistance (CaDNetASR). Clarification was sought from individual producers when necessary between March 2020 and June 2020. Questions included SCC cut offs, mastitis history and type of antimicrobials used.

Criteria for farm inclusion were a minimum number of 50 lactating cows, raising own replacement heifers, and participation in the Canadian Dairy Herd Improvement program offered by Lactanet (Guelph, ON, Canada). Data were collected using the online platform REDCap. Data cleaning and analysis were performed using RStudio (RStudio Team, 2019). Outcomes of interest were dry cow therapy (SDCT vs. BDCT), CM treatment (selective vs. blanket) and teat sealant use. Associations between the outcome variables, questions and potential confounders were explored using Chi-square tests on contingency tables, and Welch's t-tests. In addition, Kendall rank correlations between geographic regions, milking systems and AMU practices were made.

RESULTS

FARM DESCRIPTIVE STATISTICS

A total of 146 dairy producers from 5 Canadian regions completed the structured questionnaire (Alberta n = 30, British Columbia n = 28, Nova Scotia n = 27, Ontario n = 31, Quebec n = 30). Herd sizes varied from 36 to 560 lactating dairy cows, with a mean of 140 cows (Table 1).

Table. 1. Description of herd size per province.

Region	No. farms	Min. cows	Max. cows	Mean	Median
National (Canada)	146	36	560	140	108
Alberta	30	58	560	171	152
British Columbia	28	68	320	175	161
Ontario	31	44	482	160	180
Nova Scotia	27	36	352	107	80
Quebec	30	42	298	86	74

The majority of farms had free-stall barns (66%), whereas 20% had tie-stalls. Furthermore, 13% of producers provided more than one answer regarding housing type, with the most frequent combination being free-stall with other housing (32%, Appendix 2 Table A1). In British Columbia and Alberta, tie-stalls were absent. One producer did not provide an answer to the housing type question. A correlation was found between housing type and milking system (Kendall rank correlation = 0.67); pipeline was only used in tie-stalls and 90% of included automated milking system (AMS) farms had free-stall housing in the present study. The most frequently used type of milking system was parlour (48%), followed by automated (28%) and pipeline (23%). A combination of pipeline and AMS was used by one producer (Appendix 2 Table A1). On 62% of farms, AMU protocols for diagnosis and treatment of common diseases were available.

DRY COW THERAPY

In the study population, BDCT was more commonly practiced (65% of producers) compared to SDCT. One producer reported not using any DCT. There was no difference in mean herd size between farms applying BDCT versus SDCT (145 vs. 132; t = 0.76, df = 107, P = 0.45). In addition, no association was found between type of DCT and type of milking system used (Chi-square = 0, df = 1, P = 1.00), as well as the type of DCT applied and housing type (Chi-square = 0, df = 1, P = 1.00). As presented in Figure 1, there was no difference in proportion of producers who applied DCT between the five regions (Chi-square = 2.16, df = 4, P = 0.71).

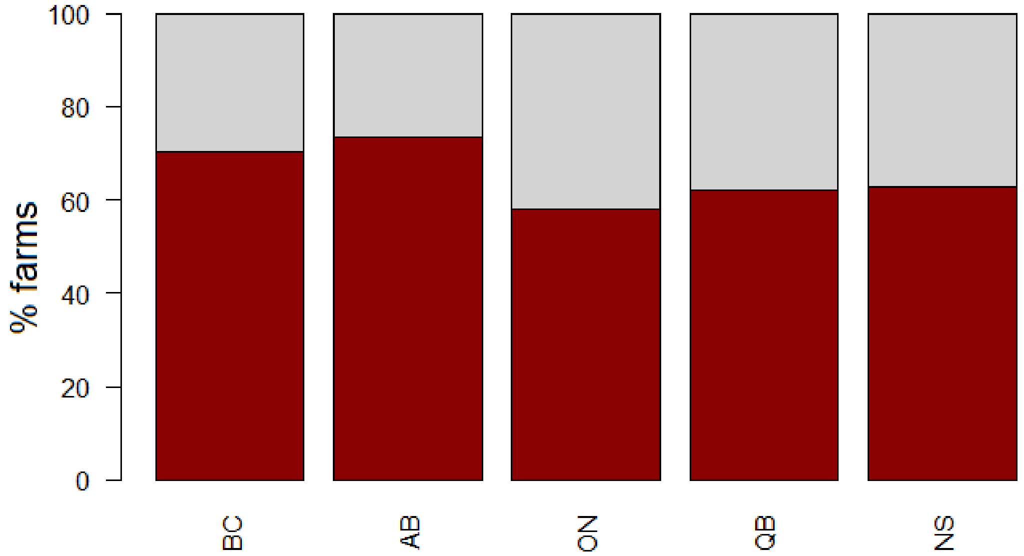

Figure 1. Type of DCT applied per province, red = BDCT, grey = SDCT.

Written DCT protocols were present at 29% of farms. Producers reported that the majority of those protocols (88%) were developed in collaboration with the herd veterinarian. Producers using SDCT were asked which factors they consider in their antimicrobial treatment decision making. Of producers enacting SDCT (n = 50), 86% used SCC thresholds to select cows to treat with antimicrobials at dry-off. SCC thresholds used to select cows for DCT ranged from 15,000 to 500,000 cells/mL, with the majority of producers using 150,000 - 200,000 cells/mL (median = 150,000, Figure 3). Whether or not different thresholds were employed for primiparous and multiparous cows was not asked. However, one producer specifically indicated that a different cut-off was used (100,000 cells/mL for primiparous cows and 150,000 cells/mL for multiparous cows).

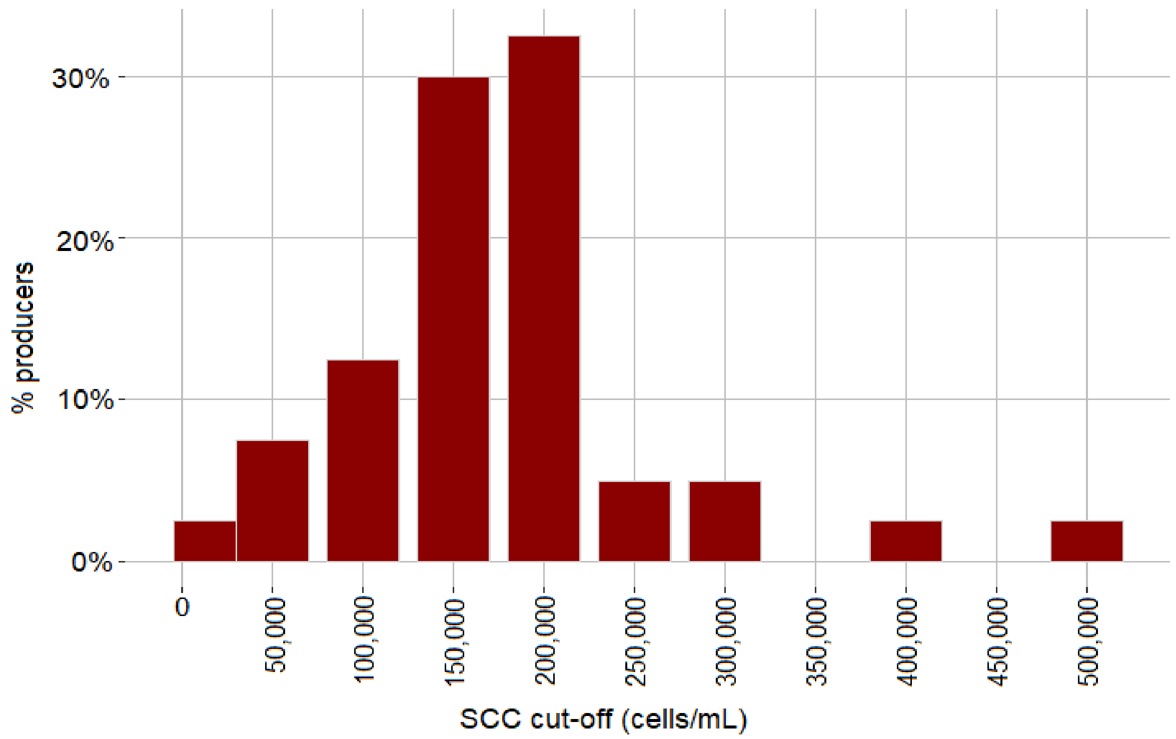

Figure 2. SCC cut-off values used to select cows to treat with antimicrobials at dry-off (n = 40). Answers not included (n = 2): *"In the 1% high SCC"*, *"100,000 for primiparous, 150,000 for multiparous cows"*.

Of producers using SDCT, 75% considered information on previous CM cases to select cows to treat with antimicrobials at dry-off. This varied from time point of CM case (used by 45% of SDCT producers, mostly current lactation), to number of CM events within a defined timeframe or lactation (used by 33% of SDCT producers, mostly in the same lactation) and suspected or confirmed bacteria (used by 8% and 24% of SDCT producers, respectively, Appendix 2 Table A2). Furthermore, of producers applying SDCT, 20% used only SCC thresholds to select cows, while 8% used solely information on previous CM cases (Figure 3). A combination of both was used by 65% of producers. No correlation was found between specific combinations of selection criteria used (Kendall rank correlation < 0.60). Interestingly, the four producers not using SCC thresholds all used only one other selection criteria instead; two considered the number of CM events, and two used the time point of the previous CM event.

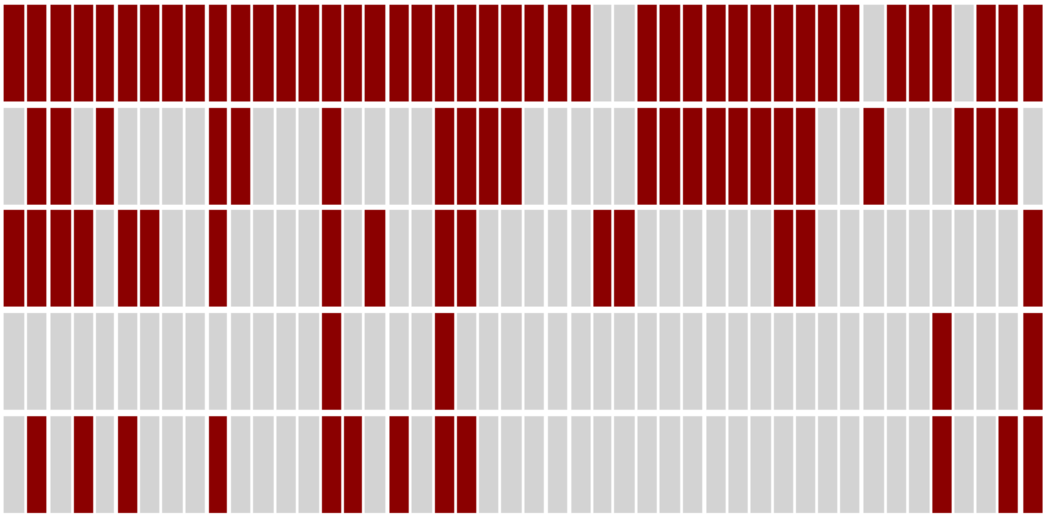

Figure 3. Heatmap of SCC and specified information on past CM cases used to select cows for SDCT (n = 46). One column indicates one farm. Red = used, grey = not used.

In addition to SCC thresholds and information on previous CM cases, other criteria were mentioned by 46% of SDCT producers. Those included milk production (10%) and season (8%), among other criteria. Comprehensive data is found in Appendix 2 Table A4.

USE OF TEAT SEALANT

The majority of producers (59%) administered internal teat sealant to all cows at dry-off. This was not different between farms using BDCT or SDCT (Chi-square = 0.02, df = 1, P = 0.89). In addition, no difference was found in use of teat sealant in all cows between provinces (Chi-square = 4.80, df = 4, P = 0.31). Producers using teat sealant had a higher mean herd size than producers not using teat sealant (155 vs. 118; t = 2.24, df = 131, P = 0.03). For milking systems, an association was found with teat sealant use; more teat sealant was used in farms with a parlour compared to pipeline system (Chi-square = 4.21, df = 1, P = 0.04, Figure 4).

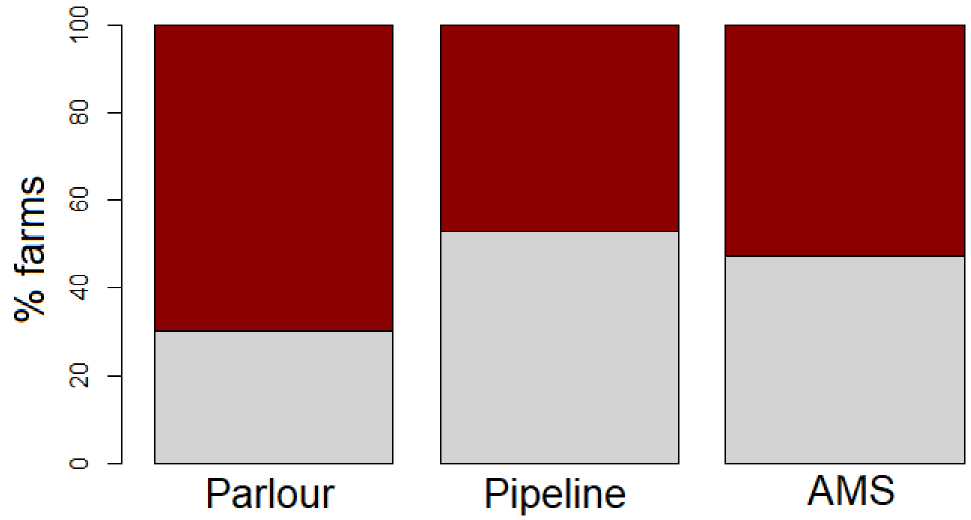

Figure 4. Association between teat sealant use and milking system, red = teat sealant used, grey = no teat sealant used.

CLINICAL MASTITIS TREATMENT

Selection of CM cases for antimicrobial treatment was done by 60% of producers. No association was found between the type of CM therapy applied (blanket vs. selective) and province (Chi-square = 8.16, df = 4, P = 0.09). There was no difference in mean herd size between farms applying selective CM treatment versus blanket CM treatment (t = 0.49, df = 46.97, P = 0.62). Of producers using selective CM treatment (n = 85), 41% used SCC thresholds to select cows to receive antimicrobials, usually considering the last SCC record (56%). SCC thresholds used ranged from 150,000 to 1,000,000 cells/mL, with the majority of producers using 200,000 - 300,000 cells/mL (median = 300,000). In Figure 5, two distinct groups can be identified with producers using ≤ 500,000 cells/mL as cut-off and producers using > 500,000 cells/mL as cut-off.

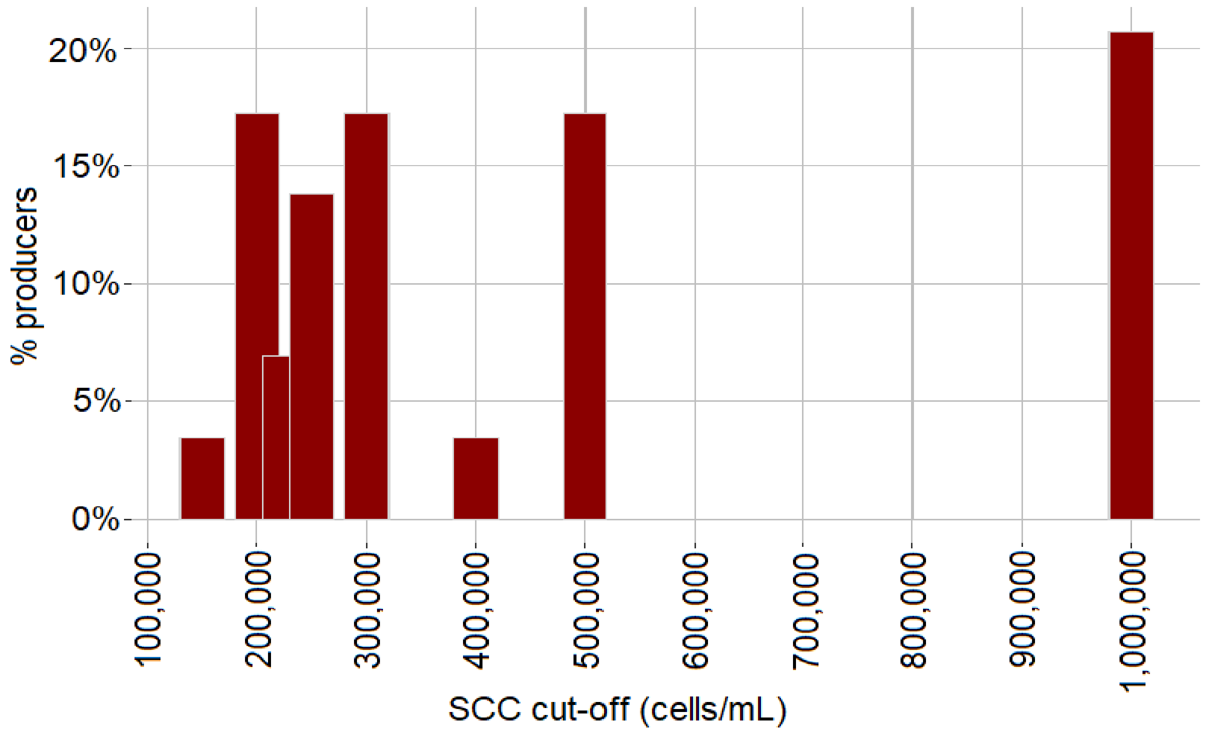

Figure. 5. SCC cut-off values used for selective CM therapy (n = 29). Answers not included (n = 4): *"Attention list robot", "No cut off used", "No real cut off value", "Variable"*. 2 producers did not provide an answer.

Of producers applying selective CM treatment, 60% used information from previous CM cases to select cows to receive antimicrobial treatment. The most frequently used information from previous CM cases was the number of CM events (59%), mostly regarding events in the current lactation (75%). Similarly, the majority of producers used previous CM case information from the current lactation (Appendix 2 Table A3). A combination of information from previous CM cases and SCC thresholds were used by 36% of producers who applied selective CM treatment. Only information on previous CM cases was used by 24% of producers, while 5% of producers used solely SCC thresholds to select cows.

No correlation was present between combinations of specific selection criteria used for selective CM treatment (Kendall rank correlation < 0.60). The combinations of criteria used by producers are displayed in Figure 6 and indicate that various selection criteria are used in decision making for selective CM treatment.

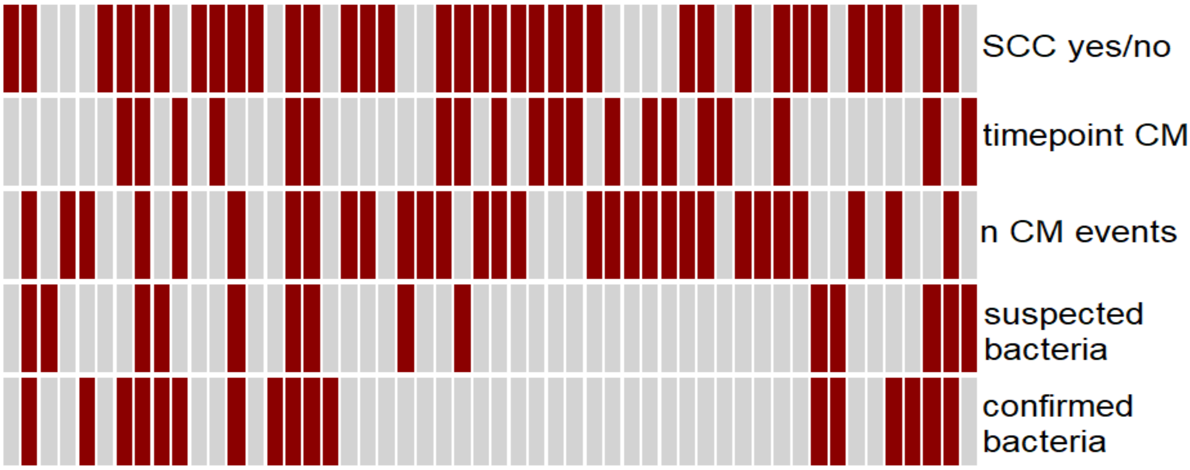

Figure. 6. Heatmap of SCC and specified information on past CM cases used to select cows for SCM therapy (n = 52). One column indicates one farm. Red = used, grey = not used.

Producers could indicate the importance of several factors when deciding whether to treat CM with antimicrobials. Options ranged from 1 (very important) to 5 (not important). Factors most frequently considered ‘very important’ or ‘important’ were severity of the symptoms (94%), confirmed or suspected bacteria (66%), and mastitis history (64%). Factors considered less important were culling and replacement costs, need for milk to fill quota, and age and genetics of the cow (Figure 7).

Written treatment protocols for mastitis were present at 50% of farms. The majority of those protocols (92%) were developed in collaboration with the herd veterinarian. Furthermore, of the CM cases that were treated with antimicrobials, 65% of producers applied only IMA without SYA for the majority (> 75%) of CM cases. Solely SYA was applied by 2% of producers in more than 75% of CM cases. Both IMA and SYA were applied in more than 75% of CM cases by 17% of producers.

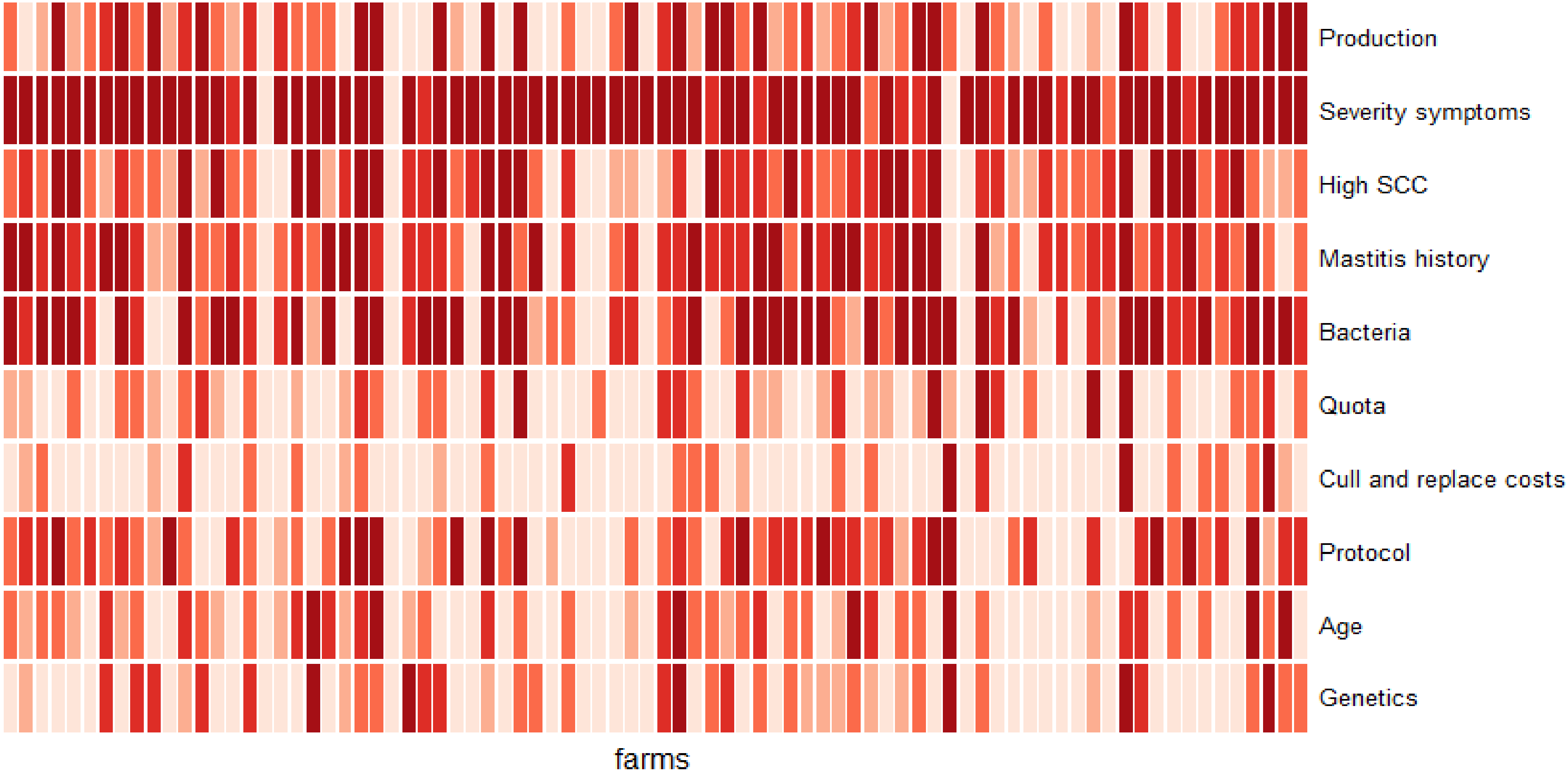

Figure 7. Heatmap of importance factors when deciding whether to treat a mastitis cow with antimicrobials (dark red = very important, white = not important). One column indicates one farm (n = 82).

SDCT AND SELECTIVE CM TREATMENT

Both SDCT and selective CM treatment were used by 26% of producers, whereas 32% applied no SDCT or selective CM treatment at all (Table 2).

Table 2. Proportions of farms using combinations of selective DCT and CM therapy.

	Selective CM	Blanket CM
BDCT	32%	34%
SDCT	8%	26%

DISCUSSION

This study quantified DCT and CM practices on Canadian dairy farms. In summary, BDCT was the norm in every province, compared to SDCT (Figure 1). Selection criteria used most frequently when deciding whether to treat a cow with antimicrobials at dry-off were SCC thresholds and information on previous CM cases. The majority of producers administered teat sealant to all cows at dry-off. Herd size and milking system (Figure 4) were associated with teat sealant use. Selective treatment of CM was used by 60% of producers. Information on previous CM cases, mostly based on information from the current lactation, was used most frequently to select cows for antimicrobial CM treatment. In summary, selection criteria considered most important when deciding on DCT and antimicrobial CM treatment became clear from this study. However, whether those criteria were used to decide in favour of or against antimicrobial treatment needs to be clarified.

FARM CHARACTERISTICS

Mean herd size in this study (140 cows) was higher than the Canadian average of 93 cows (Canadian Dairy Information Centre, 2019b). This can be explained by the exclusion of herds with less than 50 cows, equal distribution of the study population across provinces, and farms chosen from certain representative sites within each province. Herds in British Columbia and Alberta are larger than the rest of Canada, and represented 40% of our study farms, while in Canada, they represent less than 10% of dairy farms (Canadian Dairy Information Centre, 2019a). Some herds in Quebec (n = 6), Nova Scotia (n = 4) and Ontario (n = 2) had slightly less than 50 cows. The 50-cow inclusion criterion was set to facilitate other parts of the CaDNetASR project, and was not needed to reach the objectives of the current study. For this study, information regarding DCT and CM treatment practices was considered to be most important, which was provided by smaller farms as well. Thus, they were not excluded from the data.

In the present study, the majority of farms (66%) had free-stalls and 20% had tie-stalls (Appendix 2 Table A1), whereas Canadian reports indicate an opposite distribution of housing systems (Canadian Dairy Information Centre, 2019a). This can be attributed to exclusion of farms with less than 50 cows as well. Dairy herds housed in tie-stalls are typically smaller than herds housed in free-stalls (Barkema et al., 2015). Thus, some tie-stall farms may have been systemically excluded from this study, which is visible in the distribution of housing systems in Ontario. Another reason is the difference in distribution between the study population and Canadian dairy farms, as explained before. The majority of Canadian dairy farms is located in Quebec, and 91% of them have tie-stalls (Canadian Dairy Information Centre, 2019a). In the present study, only 21% of farms were located in Quebec, which explains the lower proportion of tie-stall barns, compared to Canadian reports. In addition, combinations of housing systems were reported. As presented in Appendix 2 Table A1, all combinations included a free-stall. Although only a few producers indicated having additional housing, it is likely that more producers do. In summary, herd size and housing system reported in the present study are not perfectly representative of the Canadian dairy industry. As a consequence of deviating herd sizes from national averages and the disproportional distribution of farms, extrapolation of the study results should be done carefully. Nonetheless, the results have provided valuable insight into current DCT and CM therapy practices in Canada.

DRY COW THERAPY

SDCT aims to identify cows who would benefit from IMA at dry off (Lhermie et al., 2018). Therefore, only those cows with IMI, or cows at risk of developing mastitis during the dry period will receive IMA. Selection methods like using SCC thresholds and information on previous CM cases were described in this study. Furthermore, combinations of selection criteria were used by producers. In addition, using CM incidence (Scherpenzeel et al., 2016b) and bacteriology (Osterås and Sølverød, 2009) are reported to be important as well when selecting cows for DCT.

In a Canadian study by Bauman et al. (2018) conducted in 2015, 84% of producers (n = 374) used BDCT, whereas in the present study, 65% of producers used BDCT. This shows a potential decrease in BDCT use in Canada over the past few years. Increasing pressure to reduce AMU on dairy farms (Cameron et al., 2015; Swinkels et al., 2015) may contribute to this decrease. Unlike some other countries (Osterås and Sølverød, 2009; Swinkels et al., 2015), applying BDCT is not forbidden in Canada. This sometimes makes comparing DCT practices in Canada with those in other countries difficult, because legislation differs.

SCC thresholds are most commonly used as selection criteria for DCT (Cameron et al., 2014); however, culture-based methods or a combination of methods can also be used (Torres et al., 2008; Cameron et al., 2015). SCC thresholds are frequently used in the current study population, along with information on previous CM cases. The most frequently used SCC cut-offs were 150,000 - 200,000 cells/mL. This is in agreement with the 200,000 cells/mL cut-off that has been described before in the US and Italy, among other countries (Vasquez et al., 2018; Zecconi et al., 2019). However, country differences in, for example, legislation and herd characteristics should be considered (Zecconi et al., 2019).

Number of SCC records considered is also of importance, as efficiency increases with the number of records used, reaching an optimum sensitivity and specificity at three records (Torres et al., 2008). Although information regarding SCC records used in SDCT was available in this study, it is unclear how frequently each producer received SCC records. Consequently, clarification regarding timeframes of SCC records used by producers should be sought in the future. In addition to SCC thresholds, information on previous CM cases is important to take into consideration as well (Osterås and Sølverød, 2009), as they can indicate the presence of a chronic or subclinical case. Subclinical mastitis has been described to cause welfare issues and production losses, although clinical signs (e.g. fever, swelling of the udder) are absent (Peters et al., 2015). Information on previous CM cases was used by 75% of SDCT producers, mostly considering the current lactation. This is consistent with the description of a low-risk cow by Vasquez et al. (2018).

Although a lower adoption of SDCT can be expected among larger herds, as described by a study in Finland (Vilar et al., 2018), this was not the case in our study population. This can be partially explained by the absence of legislation in Canada. Furthermore, herds in the Finnish study were smaller (78% had < 60 cows), and the study population was larger (n = 715 farms).

USE OF TEAT SEALANT

At dry-off, internal teat sealant use alone has the same effect on SCC in early lactation as in combination with IMA (Cameron et al., 2015; Dufour et al., 2019; Kabera et al., 2020). Furthermore, teat sealant could significantly reduce the risk of new IMI, compared to both IMA

(Huxley et al., 2002) and no treatment (Dufour et al., 2019). Thus, a higher adaptation of teat sealant could be expected among producers using SDCT. However, no association was found between use of teat sealant and type of DCT applied in this study. We only focused on teat sealant administration to all cattle at dry-off; therefore, partial herd teat sealant use was not included or considered in correlations. There did appear to be an association between teat sealant use and milking system; producers with parlour used teat sealant more frequently compared to producers using pipeline. Furthermore, teat sealant use was associated with a higher mean herd size. The effect of DCT on the association between herd size and teat sealant use has not been looked at. Confounding factors, such as housing or province, may have impacted those findings. So, associations found need to be interpreted very carefully.

CLINICAL MASTITIS THERAPY

Similarly to SDCT, cows that are capable of clearing infections by themselves should be identified and excluded from antimicrobial CM treatment, as well as cows suffering from CM caused by pathogens not being susceptible for antimicrobials (Lago et al., 2011). Furthermore, in CM cases without a bacterial cause, AMU is not effective and therefore unnecessary (Kayitsinga et al., 2017).

Limited literature is available regarding adoption of selective CM treatment. Few studies in the US reported proportions of CM cases treated per farm, or proportions of farms treating all cows. For example, Raymond et al. (2006) reported that 88% of producers treated most of their affected cows with antimicrobials. More recently, 87% of CM cases were treated with antimicrobials in 2014 (USDA, 2016). Similarly, 90% of CM cases were treated in a Canadian study by Aghamohammadi et al. (2018). Although no direct comparisons can be made, it illustrates the situation in Northern America. In the present study, the proportion of producers treating every CM case with antimicrobials was lower (40%) suggesting that selective CM treatment might be upcoming.

When selecting CM cases to treat with antimicrobials, SCC thresholds are reported to be one of the most important selection criteria (Osterås and Sølverød, 2009). This is an easy and practical method to identify udder health status (Zecconi et al., 2019). In a study conducted in the North-Eastern US, 49% of producers enacting selective CM treatment used SCC thresholds (Kayitsinga et al., 2017). Similarly, of producers using selective CM treatment in this study, 41% used SCC thresholds. Moreover, of producers using SCC thresholds, 37% reported using 500,000 cells/mL or 1 million cells/mL as SCC cut-off. Although it is unclear whether selection criteria were used to decide against or in favour of antimicrobial treatment, it is possible that cows with higher SCC thresholds do not receive antimicrobial treatment, because they are considered chronically infected. In these cases, it is possible that producers will withhold antimicrobial treatment until dry-off or cull the animal from the herd. Moreover, only information regarding individual SCC thresholds used was available. Selection criteria regarding bulk milk SCC values were not asked in the questionnaire, although bulk tank milk contains a lot of valuable information (e.g. regarding milk quality and pathogen presence) (Bauman et al., 2018). Therefore, additional information needs to be collected in order to understand producers' motivation to use specific SCC thresholds.

When deciding whether to treat a CM case with antimicrobials, severity of symptoms was listed as 'very important' or 'important' by 94% of the producers who selectively treated CM. This is in line with a study by Raymond et al. (2006), where 94% of producers based their decision for treatment with antimicrobials upon symptoms. Severe cases need immediate treatment, as those cows are at risk of dying. While mild and moderate cases can usually wait for culture results (Roberson, 2012).

Use of bacteriology has been described as one of the most important factors in mastitis management (Osterås and Sølverød, 2009). With bacteriology, also referred to as bacteriologic culture, bacteria causing CM can be identified (Cameron et al., 2014). In the present study, confirmed or suspected bacteria was listed as 'very important' or 'important' by 66% of producers who selectively treated CM in our data, whereas only 19% of producers in the study by Raymond et al. (2006) based their decision on positive culture results. However, Raymond et al. (2006) only included confirmed cases, which number is unknown in the present study as we combined suspected and confirmed cases. The number of producers who view confirmed bacterial causes important in their treatment decision might be smaller than 66%. In addition, the study by Raymond et al. (2006) was conducted in the US and dates from 15 years ago; use of bacteriologic culture might have increased. Overall, using bacteriological culture to guide decisions on CM treatment is a very informative tool as it confirms CM cases with a bacterial cause, thus enabling selection of CM cases to receive IMI treatment, leading to a decreased IMA use (Lago et al., 2011), thus an important factor improve prudent AMU for CM treatment (Oliveira and Ruegg, 2014).

For treatment of severe CM cases, SYA is highly recommended, yet it is not usually necessary for mild and moderate CM cases (Roberson, 2012). Although no information on severity of specific CM cases was available, 17% of producers in the present study frequently used SYA in addition to IMA. Another 2% of producers frequently used solely SYA. Similarly, 25% of participants reported using SYA for CM treatment in a study conducted in the US (Kayitsinga et al., 2017). In the same study, more producers used IMA to treat the majority of their cases, compared to use of SYA. This is in agreement with the results of the present study.

USE OF TREATMENT PROTOCOLS

The majority (62%) of producers questioned reported to have written treatment protocols available for common diseases. Not only having treatment protocols, but also complying with them is important on dairy farms (Kayitsinga et al., 2017). However, producer compliance to protocols was unclear in the present study. In a study conducted in 2005 in the US, the majority of producers agreed that using treatment protocols could reduce production losses as well as errors, especially when working with farm staff; however, only 27% of producers reported having treatment protocols for common diseases (Raymond et al., 2006). Increasing availability of and compliance with treatment protocols could reduce on-farm AMU (Osterås and Sølverød, 2009), and subsequently, minimize AMR development (Vasquez et al., 2018), although the exact relationship between dairy AMU and the development of AMR remains unclear (Saini et al., 2012; Tang et al., 2017; Nobrega et al., 2018).

FUTURE DIRECTIONS

Using the outcomes of this analysis, a second questionnaire will be developed in order to gain a more detailed understanding of selection criteria and producers' perception towards their effect on the herd's udder health. Among other information, the proportion of cows receiving antimicrobials at dry-off and in CM cases should be clarified. In addition, information regarding CM incidence, selection criteria for teat sealant use, and compliance with written treatment protocols is needed. Also, whether selection criteria for DCT and CM treatment are used to decide against or in favour of antimicrobial treatment needs to be clarified.

To understand how producer decisions are made regarding AMU for CM and DCT, insight into human behaviour and producer perceptions is required. However, little is known regarding producer perceptions, external influences (i.e. by veterinarians and peers) and their decision making process (Swinkels et al., 2015; Scherpenzeel et al., 2016b). Furthermore, making decisions regarding DCT is farm dependent and complex for veterinarians as well as producers (Higgins et al., 2017). Future study group aims are to inform SDCT and CM treatment practices in Canada.

CONCLUSIONS

BDCT is still the norm in Canada, but adoption of SDCT is increasing. Selection criteria most frequently used for SDCT are SCC thresholds and information on previous CM cases. For antimicrobial CM treatment, information on past CM cases is most frequently used, mostly based on the current lactation. The majority of dairy producers uses teat sealant at dry-off. Use of treatment protocols for AMU still has the potential to increase. Describing current practices is an important step in understanding DCT and CM treatments and highlight possibilities to reduce AMU.

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APPENDIX 1: CaDNetASR questionnaire

1. Herd ID: ____________
2. Date: ______________

DRY COW THERAPY

1. Do all cattle receive teat sealant at dry-off?
☐Yes
☐No

2. Do all cattle receive intramammary antibiotics at dry-off?
☐Yes
☐No

3. Do you use SCC to select cattle to treat with antibiotics at dry-off?
☐Yes
☐No (→ Q6)

4. Which SCC record do you use?
☐Last record
☐Last two records
☐Last three records
☐SCC of the past __ months
☐Other: ____________

5. What SCC cut-off do you use?
☐150,000
☐175,000
☐200,000
☐250,000
☐300,000
☐Other: ______

6. Do you use previous mastitis history to select cattle to treat with antibiotics at dry off?
☐Yes
☐No (→ Q8)

7. What mastitis history specifically?

☐Timepoint of previous clinical mastitis case
- ☐Current lactation
- ☐Past month
- ☐Past two months
- ☐Past three months
- ☐Other: _________

☐Number of mastitis events
- ☐More than ___ events in the same month
- ☐More than ___ events in the same lactation
- ☐More than ___ events in the previous lactation
- ☐Other: _________

☐Suspected pathogen
☐Confirmed pathogen
☐Other: _____

8. Do you use additional criteria to select cattle for antibiotic dry cow therapy?

☐Yes: ___________________________
☐No

CLINICAL MASTITIS TREATMENT

9. Are all clinical mastitis cases treated with antibiotics??

☐Yes
☐No

10. Do you use SCC to select cattle to treat with clinical mastitis to treat with antibiotics?

☐Yes
☐No (→ Q13)

11. What SCC record do you use?

☐Last record
☐Last two records
☐Last three records
☐SCC of the past __ months
☐Other: ______________

12. What SCC cut-off do you use?

☐150,000
☐175,000

☐200,000
☐250,000
☐300,000
☐Other: ______

13. Do you use clinical mastitis case history to select cattle to treat with antibiotics?
☐Yes
☐No (→ Q15)

14. What mastitis history specifically?
☐Timepoint of previous clinical mastitis case
    ☐Current lactation
    ☐Past month
    ☐Past two months
    ☐Past three months
    ☐Other: ________
☐Number of mastitis events
    ☐More than ___ events in the same month
    ☐More than ___ events in the same lactation
    ☐More than ___ events in the previous lactation
    ☐Other: ________
☐Suspected pathogen
☐Confirmed pathogen
☐Other: _____

15. How important are the following factors when deciding whether to treat a mastitis cow with antibiotics? (Rank from 1 to 5, 1 being a very important factor and 5 being a factor that is not important)

☐Production of the cow	1	2	3	4	5
☐Age of the cow	1	2	3	4	5
☐Genetics of the cow	1	2	3	4	5
☐Severity of the symptoms	1	2	3	4	5
☐High SCC	1	2	3	4	5
☐Mastitis history	1	2	3	4	5
☐Confirmed or suspected bacteria	1	2	3	4	5
☐Need for milk to fill quota	1	2	3	4	5
☐Cull cow price and price to buy a new milking cow	1	2	3	4	5
☐Protocol established with my veterinarian	1	2	3	4	5
☐Other	1	2	3	4	5

APPENDIX 2: SUPPLEMENTARY TABLES

Table A1. Housing types and milking systems for SDCT and BDCT.

Variable	No. farms SDCT (%)	No. farms BDCT (%)
Housing type		
Free-stall	33 (35)	60 (65)
Tie-stall	10 (34)	19 (66)
Other	0 (0)	2 (100)
Free-stall + tie-stall	2 (40)	3 (60)
Free-stall + pole barn	0 (0)	3 (100)
Free-stall + pasture	2 (67)	1 (33)
Free-stall + box stall	1 (50)	1 (50)
Free-stall + loose housing	0 (0)	1 (100)
Free-stall + tie-stall + pole barn	1 (20)	4 (80)
Milking system		
Parlour	24 (34)	46 (66)
Automated Milking System (AMS)	13 (33)	26 (67)
Pipeline	11 (33)	22 (67)
Pipeline + AMS	1 (100)	0 (0)

Table A2. Selection criteria used for dry cow treatment (DCT)

Variable	Category	No. farms	% farms
Selective DCT		50	35
Blanket DCT		94	65
Protocols			
Written protocols present		42	29
Developed with vet		37	25
SCC cut-offs used		42	29
Mean = 176,625; median = 150,000			
< 100,000		4	10
100,000		5	13
150,000		12	30
200,000		13	33
> 200,000		6	15
SCC records used			
Last record		9	21
Last 2 records		4	10
Last 3 records		9	21
Records of the past __ months			
3		3	7
6		1	2
8		1	2
9		2	5
10		1	2
12		8	19
Whole lactation		2	5
Other		2	5
No. events for CM history			
Multiple events same month	> 1	1	5
	> 2		
	> 3		
Multiple events in same lactation	> 1	4	20
	> 2	4	20
	> 3	4	20
Multiple events in previous lactation	> 1	2	10
	> 2	3	15
	> 3		
Other	Any CM case in life	2	10
Timeframe used previous CM case			
Current lactation		18	82
Past month		1	5
Past three months		1	5
Current + past lactation		1	5
Past two weeks		1	5

Table A3. Selection criteria used for clinical mastitis (CM) therapy.

Variable	**Category**	**No. farms**	**% farms**
Selective		85	60
Blanket		58	40
Protocols			
Written protocols present		73	50
Developed with vet		67	46
SCC cut-offs used		35	24
Mean = 448,276; median = 300,000			
≤ 200,000		6	21
200,001 - 250,000		6	21
250,001 - 300,000		5	17
300,001 - 500,000		6	21
500,000		5	17
1,000,000		6	21
SCC records used			
Last record		19	56
Last 2 records		1	3
Last 3 records		8	24
Whole lactation		2	6
Most recent		2	6
Other		2	6
No. events for CM history			
Multiple events same month	> 1	1	3
	> 2	4	12
	> 3	1	3
Multiple events in same lactation	> 1	9	26
	> 2	9	26
	> 3	2	6
Multiple events in previous lactation	> 1	3	9
	> 2	2	6
	> 3	1	3
Other		2	6
Timeframe used previous CM case			
Current lactation		12	60
Past month		3	15
Past two months		2	10
Past three months		0	0
All of the above		1	5
Current + previous lactation		1	5
Current lactation + past month		1	5

Table A4. Specified additional criteria used for DCT selection. *Petrifilm was reported twice.

Additional criteria
2nd lactation and up get blanket dry cow
Age of the cow (< 2 years old), Mastitis Index Herd Navigator
Below 20 kg of milk
Kg milk (under 25kg no treatment), dry period length (>10wks treated)
Milk quality/production
Si lait coule facilement par terre
Low milk production animals won't be treated
High milk production, season (summer more is treated)
Season - more treated in summer
Season, genetics, where they will be housed (summer all are treated because they will be on pack)
Time on the year, summer = outside
Milk test
Bacterio
Bacterio selective
Do a milk culture on every cow before dry off, result determines whether to treat
Tri-plate bacteria on farm
Petrifilm*
Conductivity
Does not dry treat
Dryclox availability
Herd navigator LDH peaks
Increase in SCC