Article

Gastrointestinal nematode management in western Canadian cow-calf herds

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Abstract — There is a paucity of information from western Canadian beef cow-calf producers about how they control gastrointestinal nematodes. The objectives of this study were to describe cow-calf producers' management practices related to control of gastrointestinal nematodes including pasture management and use of parasite control products. A questionnaire was distributed to 105 producers in May 2015. Responses from 97 producers revealed the almost uniform dependence on the use of a pour-on macrocyclic lactone parasite control product in the fall as part of a routine farm management program. Control of external parasites was the primary reason for treatment, while none of the producers chose to treat specifically to manage internal parasites. The predominant management practices identified through this study increase the risk of development of anthelmintic resistance. The results also highlight the need to raise awareness of the importance of an evidence-based gastrointestinal nematode control program in beef cow-calf herds.

Résumé — Gestion des nématodes gastro-intestinaux dans les troupeaux vaches-veaux de l'ouest canadien. Il y a une rareté d'informations provenant des producteurs de vaches-veaux de l'ouest canadien sur la façon dont ils maitrisent les nématodes gastro-intestinaux. Les objectifs de la présente étude étaient de décrire les pratiques de gestion des producteurs de vaches-veaux relativement à la maitrise des nématodes gastro-intestinaux incluant la gestion des pâturages et l'utilisation des produits antiparasitaires. Un questionnaire fut distribué à 105 producteurs en mai 2015. Des réponses en provenance de 97 producteurs ont révélé la dépendance presque généralisée sur l'utilisation d'un produit antiparasitaire à verser sur l'animal à base de lactone macrocyclique à l'automne comme faisant partie d'un programme de routine de gestion à la ferme. La maitrise des parasites externes était la principale raison pour le traitement, alors qu'aucun des producteurs n'avait choisi de traiter spécifiquement pour gérer les parasites internes. Les pratiques de gestion prédominantes identifiées dans la présente étude augmentent le risque de développement de résistance aux anthelmintiques. Les résultats mettent également en lumière le besoin d'augmenter la sensibilisation de l'importance d'une approche factuelle à un programme de gestion des nématodes dans les troupeaux vaches-veaux.

(Traduit par D[r] Serge Messier)

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Introduction

All grazing cattle are exposed to gastrointestinal nematodes (GIN) and GIN burden contributes significantly to productivity loss in grazing herds (1). While it is challenging to quantify the economic costs of GIN burden in cow-calf herds because production effects are mostly subclinical, meta-analysis of 170 trials suggested a 2.5× greater economic benefit of GIN management to the cattle industry than the use of growth promotors (2,3).

Presently, most livestock producers administer anthelmintic treatments without diagnostic or epidemiological evidence (4). Such approaches place selection pressure on parasite populations, resulting in a reduction in parasite refugia (5,6). A reduced refugia population has been associated with development of anthelmintic resistance (AR) (7). In addition to routine "blanket" treatment as a main GIN management strategy, other choices made by producers are likely responsible for the growing reports of AR in various GIN species (8).

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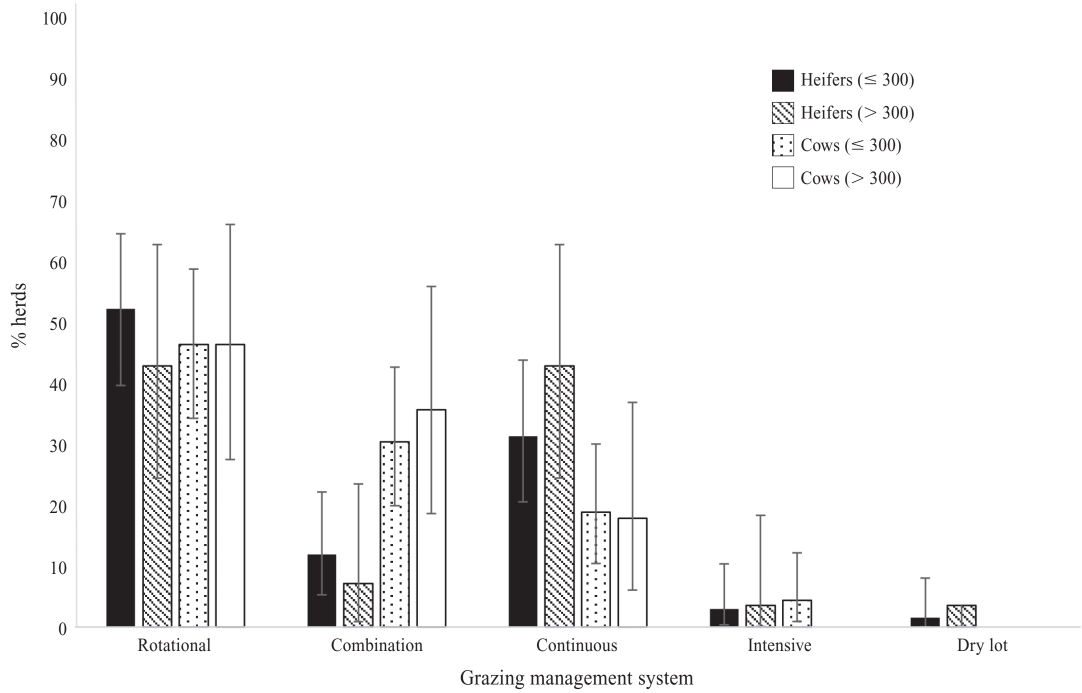

Figure 1. Percentage (95% CI) of grazing systems used by herds for cow-calf pairs ($n = 97$) and replacement heifers ($n = 95$) during the first 2 mo of the spring/summer grazing period 2015, by herd size. *Continuous grazing* is defined as cattle having free range and able to determine which areas of the entire pasture available to them they will graze. *Rotational grazing* is defined as moving cattle through different pasture types, but animal distribution is not directly managed (larger areas grazed for longer durations in rotation). *Intensive grazing* is defined as the producer determining where, when and what livestock graze at a set stocking rate and directly control animal distribution and movement, using small areas usually grazed for short durations (e.g., 1 wk.) and in the same season going back onto the same pasture.

Pasture management is also important in cattle exposure to infective third stage GIN larvae (L3). The overarching aim of pasture management related to GIN control is to reduce pasture contamination with L3 to produce "safe" pastures, and to reduce animal exposure to heavily contaminated pastures (9).

There is a paucity of information from western Canadian beef cow-calf producers about their current opinions on GIN in their herds and how they control GIN. Increasing reports of AR highlight the need to develop strategies that integrate chemical deworming with animal and pasture management practices (6,10). However, in order to recommend economical and practical GIN control practices it is important to understand the current animal and pasture management strategies and producer opinions on GIN burdens (11). Therefore, the objectives of this study were to: i) describe the current cow-calf pasture and cattle management practices as they may relate to GIN burden; and ii) define cow-calf producers' opinions towards and sources of information on GIN management.

Materials and methods

Study population

Participating producers were part of the Western Canadian Cow-Calf Surveillance Network (WCCCSN). Producer recruitment into the WCCCSN has been previously described (12,13). Briefly, enrolment was based on the last Canadian agricultural census available prior to recruitment and considered a geographically representative sample of cow-calf enterprises in the 3 prairie provinces (Alberta, Saskatchewan, and Manitoba) (14).

Producers were recruited through their herd veterinarians. Participation was contingent on a minimum herd size of 100 cows, and a willingness to complete questionnaires and allow biological sample collection. In May 2016, 105 herds were enrolled in the WCCCSN (52 in Alberta, 34 in Saskatchewan, and 19 in Manitoba) and producers associated with these herds were invited to participate in this questionnaire. Based on the preference stated at recruitment in the WCCCSN, questionnaires were administered through mailed hard copies or web formats. Multiple reminders, including a hard copy of the questionnaire, were sent to all producers who had not returned their questionnaire by August 2016.

Questionnaire design

The questionnaire consisted of 22 questions divided into 2 parts and comprising short answer, multiple-choice, and rating questions. The first section focused on herd demographics and grazing and pasture management of cow-calf pairs and replacement heifers during the spring/summer grazing period of 2015. These questions aimed to gather information about stocking density and the general method of stock/pasture management (e.g., rotation, continuous, intensive or a combination of these) and

Table 1. Months and frequency (number of producers) of administration of oral parasite control products to cows, replacement heifers, and calves from cow-calf operations in western Canada from May 2014 to May 2016.

	Cows (n = 4/95 producers)			Replacement heifers (n = 16/93 producers)			Calves (n = 8/45 producers)		
Month	Drench	In-feed or mineral mix	Combination (oral and pour-on)	Drench	In-feed or mineral mix	Combination (oral and pour-on)	Drench	In-feed or mineral mix	Combination (oral and pour-on)
January					2				
March	1						1		
April					1				
May					4		1	1	
July		1			2			1	
August	1							2	
October					1				1
November			2	1		3	1		1
December		1			2	3			1

included questions about water sources. For the purpose of this study, stocking density was categorized as < 0.5 heifer or cow-calf pair/acre, 0.5 to 1 heifer or cow-calf pair/acre, or > 1 heifer or cow-calf pair/acre.

Continuous grazing was defined as cattle having free range to graze the entire available pasture. Rotational grazing was defined as moving cattle through different pasture types without directly managing animal distribution (larger areas grazed for longer durations in rotation). Intensive grazing was defined as the producer determining where, when, and what livestock graze at a set stocking rate with direct control of animal distribution and movement, utilizing small areas for short durations (e.g., 1 wk) only and reusing the same pasture in that grazing season. Questions regarding stocking density and pasture management were asked specifically about the first 2 mo of the spring/summer grazing season, as this is the period in which the potential for significant pasture contamination with L3 larvae is expected to be greatest (1,15).

The second section of the questionnaire focused on the current GIN management practices, including the use of parasite control products, producers' opinions about GIN, and their information sources for GIN management. The survey was pre-tested with 7 cow-calf producers from Saskatchewan who were not enrolled in the surveillance network. An illustrated handbook of parasite control products registered for use in beef cattle in Canada was supplied to aid producers in answering some of the questions.

Certain management and productivity data for this study population (e.g., breeding, calving, weaning) have previously been published and were not included in this study (16).

Data analyses

All responses were entered into a commercial database (Excel 2011; Microsoft Corp., Redmond, Washington, USA) and imported into a statistical software package (StataSE version 14; Stata, College Station, Texas, USA).

Descriptive statistics were performed for each of the survey questions and depicted as frequencies, proportions [95% exact confidence interval (CI)], and mean ± standard deviation (SD) for normally distributed variable, or median [interquartile range (IQR) for non-normally distributed variable]. Some questions were not answered by all producers which is reflected in the varying denominators; proportions were calculated using available answers.

Herd size was calculated based on the maximum number of cow-calf pairs reported by each producer for the spring/summer grazing period of 2015. Herd size was categorized into those with ≤ 300 head and those with > 300 head of cattle.

Results

Description of survey responses

The response rate to the questionnaire was 92% (97/105). There were 51% (49/97) of respondents from Alberta, 35% (34/97) from Saskatchewan, and 14% (14/97) from Manitoba. Producers of herds with ≤ 300 head of cattle made up 71% (69/97) and of herds with > 300 head 29% (28/97) of respondents. Survey responses were received from June 2016 to January 2017; 73% (71/97) were received in June and July 2016. Not all responses were complete; percentages reported are for available responses for each characteristic.

Breeding herd demographics during the first 2 months of the 2015 spring/summer grazing period

During the spring/summer grazing period, producers reported a median of 197 (range: 58 to 2700; IQR: 180) cow-calf pairs, 40 (range: 0 to 575; IQR: 56) replacement heifers, and 4 (range: 0 to 84; IQR: 10) dry cows. The median number of breeding management groups on each farm was 5 (range: 0 to 18; IQR: 5). Two producers did not keep replacement heifers. For the largest breeding management group reported by each producer, the median number of cow-calf pairs was 102 (range: 24 to 600; IQR: 109). Both cow-calf pairs and replacement heifers pastured together in 92% (89/97; 95% CI: 84% to 96%) of herds.

Grazing management characteristics

Sixty-one percent (58/95; 95% CI: 51% to 71%) of herds started the spring/summer grazing period in May; fewer producers began grazing their herds in June [29% (28/95); 95% CI: 21% to 40%], April [8% (8/95); 95% CI: 4% to 16%] and March [1% (1/95); 95% CI: 0% to 6%]. The median

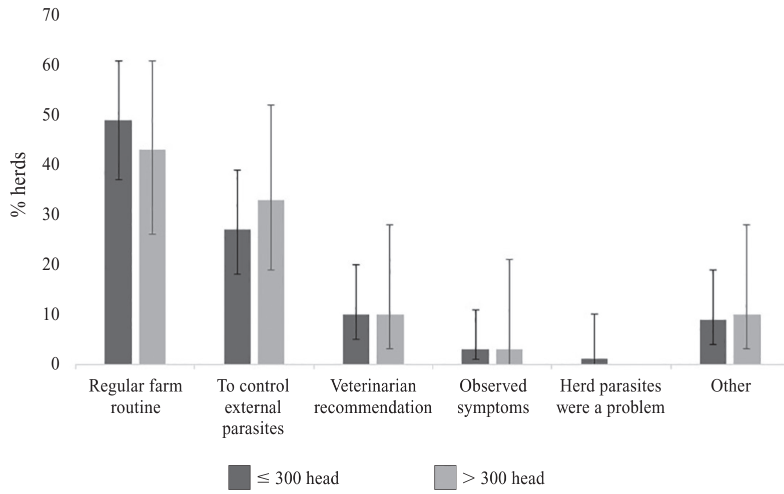

Figure 2. Percent (95% CI) of beef cow-calf producers ($n = 97$) in western Canada who describe their reason to treat with a parasite control product, by herd size (≤ 300 head, $n = 69$; > 300 head, $n = 28$).

length of the grazing period was 158 d (range: 87 to 246 d; IQR: 34 d). The end of the grazing period was October in 53% (50/95; 95% CI: 42% to 63%) of herds, November in 29% of herds (28/95; 95% CI: 21% to 40%), and December in 9% of herds (9/95; 95% CI: 4% to 17%). Five herds (5%; 95% CI: 2% to 12%) ended earlier [September (n = 3), August (n = 1), July (n = 1)]. Three herds (3%; 95% CI: 1% to 9%) ended later [January (n = 2), February (n = 1)].

Rotational grazing alone was the most common grazing system used for cow-calf pairs [46% (45/97); 95% CI: 36% to 57%] and replacement heifers [49% (47/95); 95% CI: 40% to 60%] followed by a combination grazing system approach in cow-calf herds [32% (31/97); 95% CI: 23% to 42%] and a continuous grazing management in replacement heifers [35% (33/95); 95% CI: 25% to 45%]. An intensive grazing system was used by only 3% of cow-calf herds (3/97; 95% CI: 0.6% to 9%) and 3% of replacement heifers (3/95; 95% CI: 0.6% to 9%). When the predominant grazing system was analyzed by herd size, the distribution was similar (Figure 1).

Along with the type of grazing system, producers were asked to describe their stocking density for the largest proportion of cow-calf pairs and replacement heifers. Sixty percent of cow-calf producers (58/96; 95% CI: 50% to 70%) and 59% of those raising replacement heifers (56/95; 95% CI: 48% to 69%) reported a stocking density of < 0.5 cow-calf pairs or heifers/acre, respectively. A stocking density of 0.5 to 1 heifer or cow-calf pair/acre was reported by 27% (26/96; 95% CI: 19% to 37%) and 32% (30/95; 95% CI: 22% to 42%) of cow-calf and replacement heifer producers, respectively. Finally, 13% (12/96; 95% CI: 7% to 21%) and 7% (7/95; 95% CI: 3% to 15%) of cow-calf and replacement heifer producers, respectively, stocked > 1 cow-calf pair or heifer/acre.

For cow-calf pairs, 98% (95/97; 95% CI: 93% to 100%) of producers indicated that their cattle had direct access to surface water (slough and/or dugout). For replacement heifers, 85% (81/95; 95% CI: 77% to 92%) of producers indicated direct access to surface water.

Treatment with parasite control products

Between May 2014 and May 2016, 98% of producers treated cows (95/97; 95% CI: 93% to 100%) and replacement heifers (93/95; 95% CI: 93% to 100%) at least once with a registered parasite control product, while 46% (45/97; 95% CI: 36% to 57%) treated calves at least once. The median number of treatments with a parasite control product per year was 1 in cows (minimum: 1; maximum: 4; IQR: 0.5) and replacement heifers (minimum: 0; maximum: 3; IQR 1), respectively, but 0 in calves (minimum: 0; maximum: 3; IQR: 1).

In all production groups, most producers used a parasite control product only once per year. There was no statistically significant difference in the frequency of annual treatments between herd sizes (smallest P = 0.2). Sixty-five of 69 producers with ≤ 300 cow-calf pairs used a registered parasite control product in the cows, and 83% (54/65; 95% CI: 72% to 91%) of them used a product only once per year. All 28 producers with > 300 cow-calf pairs used a parasite control product and 82% (23/28; 95% CI: 63% to 94%) used a product only once per year. Similarly, 96% (66/69) of producers with ≤ 300 cow-calf pairs used a registered control product in their replacement heifers, and 85% (56/66; 95% CI: 74% to 92%) used it once per year. Ninety-six percent (27/28) of producers with > 300 cow-calf pairs used a parasite control product in replacement heifers and of those, 81% (22/27; 95% CI: 58% to 91%) used a product once per year. Of the 45 producers who used parasite control products in their calves, 32 owned herds with ≤ 300 cow-calf pairs while 13 had > 300 cow-calf pairs. Ninety-one percent (29/32; 95% CI: 75% to 98%) of small herd producers and 77% (10/13; 95% CI: 46% to 95%) of large herd producers treated their calves once per year.

November was the month in which most cows [45% (43/95); 95% CI: 35% to 56%] and replacement heifers [42% (39/93); 95% CI: 32% to 53%] were treated. For the 45 herds that reported the date of treatment for calves, the pattern of most frequent application was split with 51% each (23/45; 95% CI: 36% to 66%) treating between March to May and between October and December.

For herds that reported the method of application for each animal production type, a topical pour-on was used alone or in combination by 99% (94/95; 95% CI: 94% to 100%), 95% (88/93; 95% CI: 88% to 98%), and 87% (39/45; 95% CI: 73% to 95%) of producers to deworm cows, replacement heifers, and calves, respectively. In-feed or mineral mix administration, alone or in combination, was comparatively rare. Three percent (3/95; 95% CI: 0.7% to 9%) and 1% (1/95; 95% CI: 0.02% to 6%) of producers used an oral drenching product or an in-feed/mineral mix in cows, respectively, while replacement heifers were treated with a drench formulation or in-feed/mineral mix alone or in combination by 17% (16/93; 95% CI: 10% to 26%) of producers. Eighteen percent (8/45; 95% CI: 8% to 32%) of producers used an oral drench or in-feed/mineral mix alone or in combination with a pour-on in their calves. Table 1 shows the months and frequency of oral anthelmintic product administration to cows, replacement heifers, and calves. Injectable was the other route of administration but this was only used by 2 producers to treat calves.

Two classes of parasite control products were utilized: macrocyclic lactones (ML) and benzimidazoles (BZ) (or a combination of the 2). For all animal production types, the most commonly used parasite control product class was an ML in 99% (94/95; 95% CI: 94% to 100%), 95% (88/93; 95% CI: 88% to 98%), and 87% (39/45; 95% CI: 73% to 95%) of cows, replacement heifers, and calves, respectively. All drenches and in-feed/mineral mix products contained BZ as the active ingredient. Overall, 16 herds treated their animals with a BZ product at least once: 10 herds with $\leq$ 300 head and 6 herds with $>$ 300 head.

When applying parasite control products, 76% (73/96; 95% CI: 66% to 84%) of producers applied visual estimation of the animal's weight to calculate the dose required, while 14% (13/96; 95% CI: 7% to 22%) used a weigh scale. The remaining 10% (10/96; 95% CI: 5% to 18%) used other methods, including estimated weight averages based on records. When herd size was examined, the use of a weigh scale was similar for large herds (14%; 4/28) and small herds (13%; 9/69) ($P = 0.9$).

Producer opinion on gastrointestinal nematode management

Producers were asked about their most important reason for choosing to use a parasite control product. Of the 97 responses, 47% (95% CI: 38% to 58%) stated that their main reason to treat was 'routine herd management practice' (Figure 2). The most important reason for 29% (95% CI: 21% to 39%) of producers was to "control external parasites" and 10% (95% CI: 6% to 18%) indicated they did so on the 'recommendation by their veterinarian'. Although that answer option was available, none of the producers chose to use a product specifically for the "control of internal parasites."

Veterinarians were the main source of information regarding parasite control product choice for 66% (95% CI: 56% to 75%) of producers. Drug product representatives were the main source for another 20% (19/97; 95% CI: 13% to 29%) and the remaining 14% (14/97; 95% CI: 9% to 23%) reported personal experience or knowledge from literature such as cattlemen's magazines as their primary information sources.

Producers were asked to indicate, on a scale from "very important" to "not important," how product price, efficacy against internal parasites, efficacy against external parasites and ease of application influenced their product choice. Price was "important" to 68% (66/97; 95% CI: 58% to 77%) of producers, effectiveness in treating internal and external parasites was "very important" for 61% (59/97; 95% CI: 51% to 70%) and 63% (61/97; 95% CI: 53% to 72%), respectively, while ease of application was "important" for 54% (52/97; 95% CI: 43% to 63%).

Diagnostic monitoring of gastrointestinal nematode infection

Lastly, producers were asked if fecal egg counts (FEC) had been used in the past 3 y to monitor GIN burden in their cattle. Sixty-seven percent (63/94; 95% CI: 57% to 76%) indicated they had not used FEC in the past 3 y while 3 producers were unsure.

Overall, 33% (31/94; 95% CI: 24% to 43%) of producers had FEC performed. Twenty-four percent (23/94; 95% CI: 16% to 34%) sampled mature cows, 14% (13/94; 95% CI: 8% to 22%) sampled replacement heifers, 4% (4/94; 95% CI: 1% to 11%) sampled steers and 2% (2/94; 95% CI: 0% to 7%) sampled calves. No bulls were sampled.

Discussion

The primary objective of this study was to describe current management practices associated with GIN control in western Canadian cow-calf herds.

Mature cattle and replacement heifers were most commonly pastured on a rotational grazing system irrespective of herd size. It has been suggested that intensive rotational grazing systems may result in increased, or at least not reduced, GIN burdens compared to continuous grazing systems as they increase grazing closer to fecal pats and lower down the sward thereby increasing exposure to infective L3 larvae (17,18). Similarly, increased pasture stocking density has been associated with increased GIN infection (1,19). However, many factors including pasture species, rate of pasture regeneration, and frequency of rotation and stocking density influence GIN infection pressures (1,17). While rotational grazing systems were frequently used by producers in this study, for most production sites and production types this was paired with the lowest stocking density from which producers could choose. This could suggest that the risk for acquiring GIN may be lower in western Canadian cow-calf operations; however, it is important to note that defining rotational grazing systems and stocking density is difficult. Although a definition in the context of this questionnaire was supplied, producers may still have based their answers on a subjective understanding of their system or may have had to choose one of the available options even if none reflected their grazing system entirely. Therefore, its interpretation must be viewed with some caution. In terms of stocking density, cattle do not graze pastures at random; in return, fecal deposition and, therefore, the density of L3 larvae on pasture, is not evenly distributed (20). Furthermore, environmental conditions and terrain affect actual stocking density; for example, yearly variations in pasture growth because of droughts or flooding may impact the area actually available for grazing (21). Although stocking density was quantified in this study, it left room for individual interpretation. This uncertainty must be recognized when assessing the influence of stocking density on the risk of GIN infection in these herds.

The most striking information to come from producers' responses to the questionnaire is the almost uniform dependence on the use of a pour-on ML parasite control product in the fall as part of a routine management program. These preferences were not influenced by herd size. The format of the survey allowed producers to only select 1 "most important" reason for treating with a control product and an explanation for why a fall-treatment was a routine management practice was not sought. The second most selected answer was "in order to control external parasites." Given the predominance of lice infestation in cattle during winter it is likely that the "routine management practice" was mainly to target ectoparasites. Fall application is not only timely for treatment/prevention of ectoparasites, it is also practical because pregnancy diagnoses are usually conducted at this time of the year, minimizing cattle handling. While external parasite control and practicality make a blanket fall-treatment a logical choice, this practice supports the development of GIN resistance and warrants creative solutions in the future, not least because resistance of some external parasites to ML is also increasing (6,10).

Whole herd fall-treatments were also predominant amongst 14 Saskatchewan beef herds where all but 3 producers applied an ML, and amongst 246 cow-calf producers, mostly from Alberta, where 91% treated cows with an antiparasitic (22,23). Likewise, 97% of questioned Saskatchewan dairy producers also report a predominant use of ML and 73% applied whole herd treatments (24). In 2872 beef herds in 24 US states, pour-on application of MLs was the preferred choice and application was also based on routine farm schedule (25).

Compared to cows and replacement heifers for which most producers used a parasite control product at least once, only approximately half of the producers treated calves, similar to Murray et al (23). Timing of treatment administration varied more in calves compared to cows or heifers. About half of treated calves received the treatment in the early spring, presumably coinciding with pasture turnout. Similar to fall treatments applied to adult cows, spring application to calves is suboptimal for GIN control based on known epidemiology in northern temperate environments and based on the expected low GIN burden in calves at that time of the year (15). Based on results by Mackie et al (26) on beef cows and calves in Ontario, the optimal time to treat calves with a parasite control product would be late June to early July. Moving treatment of calves to this time of the year, however, presents a logistical challenge for producers who rarely handle the herd in the period after turnout.

Several management choices made by surveyed producers here have been associated with the development of AR including the potential under-dosing of animals depending on dose calculation method (e.g., visual estimation *versus* weigh scale), method of application and the blanket treatment of all animals in a herd (6,10,27). The effectiveness of pour-on products has been questioned as they have resulted in under-dosing because of variable drug uptake influenced by weather, cleanliness and coat condition, accuracy of application, and licking behavior of animals (27). All of these practices place increased selection pressures on GIN by reducing the refugia population. Obviously creating one standard guideline for managing GIN in cow-calf herds is impossible because of large variations in locations and management programs. However, some key considerations should be made to help reduce the risk of AR development. Some of these include reducing the risk of under-dosing, targeted treatments or targeted selective treatments (TST), using combinations of anthelmintic drug classes, and monitoring the effectiveness of treatments (10,28). While information on TST of cattle is increasing, ectoparasite control will continue to be important and the life cycle of many ectoparasites warrants treatment and, frequently, re-treatment of all animals in a herd (29,30). Pour-on ML products with an extended effect duration against ectoparasites are an obvious choice for many producers as lice infections are a clearly visible problem. These products are generally also safer for the animal, the environment, and the applicator than many ectoparasiticides (31,32). If cow-calf producers were to adopt a "refugia approach" and leave some animals untreated for GIN, it may be necessary for them to choose another product with a narrower range for ectoparasites in those cattle that are exempt from anthelmintic treatment. Besides the concern for AR development in GIN with the current predominant practices, there are rising concerns about ML resistance in bovine ectoparasites (33,34). It is likely that this may ultimately become a stronger motivator for cattle producers to change their current practices than the risk of GIN resistance, particularly for as long as obvious clinical signs resulting from GIN resistance are not apparent.

The results of this survey also highlight that while the use of parasite control products is highly prevalent and effectiveness of treatment against internal (and external) parasites was considered very important by most producers, fecal egg counts were rarely done. Only 32% of producers had a FEC performed in the last 3 y. The use of FEC and FEC reduction tests to monitor treatment effectiveness or to identify the need for treatment are important strategies to try to recognize AR development in herds as early as possible (35).

While herd recruitment was directly aimed at creating a representative sample of western Canadian operations, ultimately there is some degree of selection bias based on producers' motivations for participation. A 93% response rate is excellent for a questionnaire and non-response bias is unlikely to have significantly influenced the results here. Recall bias may be another source of misinformation; the questionnaire asked producers to recall herd management for the previous (2015) grazing season; it is possible that not all producers accurately remembered the requested information. Therefore, as with all voluntary response questionnaires, there are some risks in applying the results to the wider population of beef cow-calf producers. Nonetheless, the responses obtained here represent a current source of information that may be used to guide future research in western Canada, including systematic evaluation of risk factors and assessing the levels of AR in these herds. CVJ

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References

1. Stromberg BE, Gasbarre LC. Gastrointestinal nematode control programs with an emphasis on cattle. Vet Clin North Am Food Anim Pract 2006;22:543–565.
2. Hawkins JA. Economic benefits of parasite control in cattle. Vet Parasitol 1993;46:159–173.
3. Lawrence JD, Ibarburu MA. Economic Analysis of Pharmaceutical Technologies in Modern Beef Production 2007. Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, Illinois. Available from: https://ideas.repec.org/p/ags/nccsci/37560.html Last accessed February 7, 2020.
4. Kenyon F, Jackson F. Targeted flock/herd and individual ruminant treatment approaches. Vet Parasitol 2012;186:10–17.
5. Kenyon F, Greer AW, Coles GC, et al. The role of targeted selective treatments in the development of refugia-based approaches to the control of gastrointestinal nematodes of small ruminants. Vet Parasitol 2009;164:3–11.
6. McArthur MJ, Reinemeyer CR. Herding the US cattle industry toward a paradigm shift in parasite control. Vet Parasitol 2014;204:34–43.
7. van Wyk JA. Refugia — overlooked as perhaps the most potent factor concerning the development of anthelmintic resistance. Onderstepoort J Vet Res 2001;68:55–67.
8. Gasbarre LC, Smith LL, Lichtenfels JR, Pilitt PA. The identification of cattle nematode parasites resistant to multiple classes of anthelmintics in a commercial cattle population in the US. Vet Parasitol 2009; 166:281–285.
9. Ballweber LR. Endoparasite control. Vet Clin North Am Food Anim Pract 2006;22:451–461.
10. Gasbarre LC. Anthelmintic resistance in cattle nematodes in the US. Vet Parasitol 2014;204:3–11.
11. Morgan E, Charlier J, Hendrickx G, et al. Global change and helminth infections in grazing ruminants in europe: Impacts, trends and sustainable solutions. Agriculture 2013;3:18.
12. Moggy MA, Pajor EA, Thurston WE, et al. Management practices associated with pain in cattle on western Canadian cow-calf operations: A mixed methods study. J Anim Sci 2017;95:958–969.
13. Waldner CL, Parker S, Gesy KM, Waugh T, Lanigan E, Campbell JR. Application of direct polymerase chain reaction assays for *Campylobacter fetus* subsp. *venerealis* and *Tritrichomonas foetus* to screen preputial samples from breeding bulls in cow-calf herds in western Canada. Can J Vet Res 2017;81:91–99.
14. Statistics Canada, 2011. Census of Agriculture. [Homepage on the Internet]. Available from: https://www.statcan.gc.ca/eng/ca2011/index Last accessed February 7, 2020.
15. Ranjan S, Trudeau C, Prichard RK, Piche C, Bauck S. Epidemiological study of parasite infection in a cow-calf beef herd in Quebec. Vet Parasitol 1992;42:281–293.
16. Waldner CL, Parker S, 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:e0219901.
17. Stromberg BE. Environmental factors influencing transmission. Vet Parasitol 1997;72:247–256; 257–264.
18. Stromberg BE, Averbeck GA. The role of parasite epidemiology in the management of grazing cattle. Int J Parasitol 1999;29:33–39; 49–50.
19. Thamsborg SM, Jorgensen RJ, Nansen P. Internal parasitism of steers grazing extensively at different stocking rates. Acta Vet Scand 1998;39: 311–323.
20. Bryan RP, Kerr JD. The grazing behaviour of cattle in relation to the sampling of infective nematode larvae on pasture. Vet Parasitol 1988; 30:73–82.
21. Moore AD, Ghahramani A. Climate change and broadacre livestock production across southern Australia. 1. Impacts of climate change on pasture and livestock productivity, and on sustainable levels of profitability. Glob Chang Biol 2013;19:1440–1455.
22. Jelinski MD, Lanigan E, Gilleard JS, Waldner C, Royan G. Survey of gastrointestinal nematode parasites in Saskatchewan beef herds. Can Vet J 2016;57:160–163.
23. Murray CF, Fick LJ, Pajor EA, Barkema HW, Jelinski MD, Windeyer MC. Calf management practices and associations with herd-level morbidity and mortality on beef cow-calf operations. Animal 2016;10: 468–477.
24. Scott H, Jelinski M, Luby C, Uehlinger F. Endoparasite control practices on Saskatchewan dairy farms. Can Vet J 2019;60:613–618.
25. USDA. 2010. Beef 2007–08, Part IV: Reference of Beef Cow-calf Management Practices in the United States, 2007–08. USDA:APHIS:VS, CEAH. Fort Collins, CO #523.0210. Available from: https://www.aphis.usda.gov/animal_health/nahms/beefcowcalf/ Last accessed February 7, 2020.
26. Mackie KG, Menzies PI, Bateman KG, Gordon JL. An observational study of naturally occurring gastrointestinal nematode infections in a seasonal grazing cow-calf herd in southern Ontario. Can J Anim Sci 2017;97:650–657.
27. De Graef J, Claerebout E, Geldhof P. Anthelmintic resistance of gastrointestinal cattle nematodes. Vlaams Diergeneeskundig Tijdschrift 2013;82:11.
28. Charlier J, Morgan ER, Rinaldi L, et al. Practices to optimise gastro-intestinal nematode control on sheep, goat and cattle farms in Europe using targeted (selective) treatments. Vet Rec 2014;175:250–255.
29. Hoglund J, Dahlstrom F, Sollenberg S, Hessle A. Weight gain-based targeted selective treatments (TST) of gastrointestinal nematodes in first-season grazing cattle. Vet Parasitol 2013;196:358–365.
30. Merlin A, Chauvin A, Lehebel A, et al. End-season daily weight gains as rationale for targeted selective treatment against gastrointestinal nematodes in highly exposed first-grazing season cattle. Prev Vet Med 2017;138:104–112.
31. Taylor MA. Recent developments in ectoparasiticides. Vet J 2001;161: 253–268.
32. Niles GA. Toxicoses of the ruminant nervous system. Vet Clin North Am Food Anim Pract 2017;33:111–138.
33. Lifschitz A, Fiel C, Steffan P, et al. Failure of ivermectin efficacy against *Psoroptes ovis* infestation in cattle: Integrated pharmacokinetic-pharmacodynamic evaluation of two commercial formulations. Vet Parasitol 2018;263:18–22.
34. Le Gall VL, Klafke GM, Torres TT. Detoxification mechanisms involved in ivermectin resistance in the cattle tick, *Rhipicephalus (Boophilus) microplus.* Sci Rep 2018;8:12401.
35. Sutherland IA, Leathwick DM. Anthelmintic resistance in nematode parasites of cattle: A global issue? Trends Parasitol 2011;27:176–181.