Article

Gastrointestinal nematode prevalence and fecal egg counts in beef cattle from western Canada

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Abstract — Fecal samples were collected from cows (*n* = 1458), calves (*n* = 1188), and replacement heifers (*n* = 921) between 2012 and 2014 from 199 herds and generalized estimating equations were used to predict mean fecal egg counts and prevalence of egg-positive samples. Replacement heifers had the highest prevalence of Trichostrongylid-type eggs at 83% [95% confidence interval (CI): 78% to 87%], and cows had the lowest at 75% (95% C: 70% to 81%). *Nematodirus* spp. was most frequently present in calves [predicted prevalence: 34% (95% CI: 28% to 40%)]. Mean fecal egg counts were highest in calves with 5.9 (95% CI: 3.9 to 7.8) Trichostrongylid-type eggs per gram (EPG) of feces and 1.0 (95% CI: 0.7 to 1.4) *Nematodirus* spp. EPG. Although mean egg counts were low to moderate, the high prevalence highlights the need to further investigate the epidemiology of gastrointestinal nematodes in western Canada. This is particularly relevant considering management changes, increasing herd sizes, climate change, and threatening anthelmintic resistance.

Résumé — Prévalence des nématodes gastro-intestinaux et dénombrements des œufs dans les fèces chez les bovins d'embouche dans l'ouest canadien. Des échantillons de fèces furent prélevés de vaches (*n* = 1458), veaux (*n* = 1188) et génisses de remplacement (*n* = 921) entre 2012 et 2014 dans 199 troupeaux et des équations d'estimation généralisée furent utilisées pour prédire les dénombrements moyens d'œufs dans les fèces et la prévalence d'échantillons positifs pour la présence d'œufs. Les génisses de remplacement avaient la prévalence la plus élevée d'œufs de type Trichostrongylide avec 83 % [intervalle de confiance 95 % (IC) : 78 % à 87 %], et les vaches avaient la plus faible avec 75 % (95 % IC : 70 % à 81 %). Les *Nematodirus* spp. étaient présents le plus fréquemment chez les veaux [prévalence prédite : 34 % (95 % IC : 28 % à 40 %)]. Les dénombrements moyens d'œufs dans les fèces étaient les plus élevés chez les veaux avec 5,9 (95 % IC : 3,9 à 7,8) œufs de type Trichostrongylide par gramme (EPG) de fèces et 1,0 (95 % IC : 0,7 à 1,4) EPG de *Nematodirus* spp. Bien que les dénombrements moyens d'œufs étaient faibles à modérés, la prévalence élevée met en évidence le besoin de continuer d'examiner l'épidémiologie des nématodes gastro-intestinaux dans l'ouest du Canada. Ceci est particulièrement approprié considérant les changements dans la gestion, l'augmentation de la taille des troupeaux, les changements climatiques et la menace de la résistance aux produits anthelmintiques.

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Introduction

Gastrointestinal nematodes (GIN) are a threat to sustainable livestock production worldwide through productivity loss and treatment costs (1,2). While parasitic gastroenteritis (PGE), characterized by diarrhea, anorexia, and weight loss primarily affects young cattle during their first grazing season, overt clinical disease is now rarely seen in North America. This is largely because GIN control programs in cattle have relied on intensive "blanket" anthelmintic treatments aimed at preventing the accumulation of parasite burdens (3). This practice, however, has led to increasing anthelmintic resistance (AR) which has been reported from around the world, including Canada (4–6).

There is limited information on the epidemiology of GIN in beef cow-calf production systems in western Canada. Beef cow-calf herds represent an economically important sector of the Canadian agrarian economy and their demographics and management have changed in recent years (7–9). For these reasons, a better understanding of the epidemiology of GIN in beef cow-calf herds in this region is needed to develop strategic control programs which optimize production while limiting the risk of increasing development of AR. The objective of this study was to describe the prevalence and intensity of GIN infection in different animal classes of beef cow-calf herds in western Canada between 2012 and 2014.

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Table 1. Descriptive summary of fresh environmental fecal samples ($n = 3567$) collected for determination of the gastrointestinal nematode prevalence and egg count intensity from beef cows, calves, and heifers from western Canada between 2012 and 2014, by year and season of collection.

	Cows		Calves		Heifers		Overall total	
	#Samples	#Herds	#Samples	#Herds	#Samples	#Herds	#Samples	#Herds
2012							1733	95
Summer	580	33	511	31	380	20	1471	84
Fall	117	4	117	6	28	2	262	11
2013							1290	67
Summer	426	21	171	10	404	20	1001	51
Fall	83	5	161	9	45	2	289	16
2014							544	37
Summer	131	7	91	6	54	3	276	16
Fall	121	10	137	10	10	1	268	21
Overall total	1458	80	1188	72	921	48	3567	199

Materials and methods

Study population and sampling

During 2012, 2013, and 2014, fresh environmental fecal samples were collected from cows, calves, and replacement heifers from cow-calf herds in western Canada (Alberta, Saskatchewan, and Manitoba). Fresh fecal samples were collected from individual animals after observed defecation. The sample population consisted of a convenience sample of beef producers visited by a Merck Animal Health (Canada) representative or by the farm's regular herd veterinarian. There was no repeat sampling of the same properties or cattle over successive seasons or years. Date of collection, the date of last treatment with an anthelmintic, anthelmintic product name, and the animal class of the animal sampled (cow, calf or replacement heifer) were recorded where possible at time of collection. Fecal samples were individually sealed in plastic bags and shipped to the laboratory (BioCheck Veterinary Diagnostics and Technologies, Lethbridge, Alberta) with freezer packs within 24 h of collection.

Laboratory analysis

Individual fecal samples were processed using a modified Wisconsin technique according to the laboratory's protocol (BioCheck Veterinary Diagnostics and Technologies). In brief, 3 g of feces were mixed with 15 mL of a saturated sugar solution (specific gravity 1.27) to create a fecal slurry. This slurry was strained through a course sieve and placed into a test tube, which was centrifuged at 180 × *g* for 7 min. The test tube was then placed on a flat surface and filled to a slight convex meniscus with the saturated sugar solution and a cover slip was placed on top. The samples were then left to stand for at least 30 min. The cover slip was removed and placed on a microscope slide for examination at 40× magnification. This method has a reported sensitivity of detection of between 0.3 and 5 eggs per gram (EPG) (10). Gastrointestinal nematode eggs were identified microscopically based on morphology as Trichostrongylid-type, *Nematodirus* spp. or *Trichuris* spp. and reported as eggs per 3 g of feces (EP3G). Eggs per gram of feces was calculated by dividing the egg counts by the original weight of the sample. For prevalence, a sample was considered positive when at least 1 Trichostrongylid-type, *Nematodirus* spp. or *Trichuris* spp. egg was identified in a sample.

Data analyses

The data were imported into a statistical software package (StataSE version 14; Stata, College Station, Texas, USA) for analysis. Based on the collection date, samples were categorized into either the summer (June, July, August) or fall (September, October, November) collection period. Because few samples were collected in spring (March, April, May) and winter (December, January, February), they were omitted from the analyses. Samples were further classified by animal class (cows, calves, and replacement heifers). Submissions that were known to have been treated with macrocyclic lactones within 45 d or with benzimidazoles within 15 d before sample collection were also excluded from further analyses (11).

Fecal samples were described for each year, season and animal class [frequency, 95% confidence interval (CI), median interquartile range (IQR)].

The overall prevalence (95% CI) of Trichostrongylid-type eggs was estimated using generalized estimating equations (GEE) to allow for clustering within herds. The initial null or intercept only GEE model used a binomial distribution and logit link function with an exchangeable within-group correlation structure and robust standard error (to deal with overdispersion within the data). The overall mean Trichostrongylid-type EPG was also determined using a null GEE model with a negative binomial family and log link with an exchangeable within-group correlation structure and robust standard error. The prevalence (95% CI) of *Nematodirus* spp. positive samples and mean EPG for Nematodirus spp. were estimated in the same way as described for Trichostrongylid-type.

The effects of year, season, and animal class on the Trichostrongylid-type prevalence and EPG shedding intensity in cows, calves, and heifers were assessed with fixed effects introduced in the above GEE models. Each independent variable (year, season, and animal class) was forced into the final model and plausible interaction terms (year by season, year by animal class, season by animal class) were evaluated. The final GEE model for each outcome was produced by manual stepwise backwards elimination of non-significant interaction terms. Interaction terms were retained in the GEE if found to be statistically significant based on a Wald's test at a *P*-value of ≤ 0.05. The effect of retained predictor variables

Table 2. Results from the GEE models for predicted prevalence [95% confidence interval (CI)] of Trichostrongylid-type egg positive samples, accounting for clustering by herd, in 3567 beef cows, calves, and replacement heifers from 199 herds from western Canada sampled between 2012 and 2014, overall (null model) and by year and season of collection (final model).

	Prevalence (95% CI)			
	Cows	Calves	Replacement heifers	All
2012				86 (82 to 90)[a]
Summer	87 (79 to 94)	87 (81 to 94)	88 (82 to 94)	87 (83 to 91)
Fall	64 (44 to 84)	94 (89 to 97)	89 (87 to 91)	82 (70 to 94)
2013				70 (63 to 77)[b]
Summer	72 (63 to 82)	59 (36 to 83)	74 (63 to 84)	70 (63 to 78)
Fall	63 (38 to 89)	74 (59 to 89)	82 (61 to 100)	72 (60 to 84)
2014				77 (70 to 84)[b]
Summer	80 (62 to 99)	81 (68 to 95)	91 (80 to 100)	83 (73 to 93)
Fall	49 (33 to 65)	83 (75 to 91)	70 (30 to 100)	66 (55 to 77)
All	75 (70 to 81)[c]	79 (73 to 86)[d]	83 (78 to 87)[d]	78 (75 to 82)
Summer	81 (75 to 86)[e]	78 (70 to 86)[e]	82 (77 to 88)[e]	80 (76 to 84)
Fall	59 (46 to 72)[f]	84 (77 to 90)[e]	84 (73 to 94)[e]	74 (67 to 80)

[a,b] Statistically significantly different; highest $P = 0.02$.
[c,d] Statistically significantly different; both $P = 0.01$.
[e,f] Statistically significantly different; highest $P = 0.01$.

Table 3. Results from the GEE models for predicted mean eggs per gram (EPG) of feces [95% confidence interval (CI)], accounting for clustering by herd, for Trichostrongylid-type eggs in 3567 beef cows, calves, and replacement heifers from 199 herds from western Canada sampled between 2012 and 2014, overall (null model) and by year and season of collection (final model).

	Mean EPG (95% CI)			
	Cows	Calves	Replacement heifers	All
2012				6.1 (4.6 to 7.6)[a]
Summer	6.9 (3.6 to 10.2)	7.5 (3.9 to 11.2)	4.4 (2.6 to 6.2)	6.5 (4.7 to 8.5)
Fall	2.6 (1.1 to 4.0)	6.7 (3.1 to 10.3)	8.0 (2.6 to 13.4)	5.3 (2.9 to 7.8)
2013				2.9 (2.4 to 3.5)[b]
Summer	3.2 (2.2 to 4.3)	1.7 (0.7 to 2.7)	3.8 (2.3 to 5.4)	3.2 (2.4 to 4.0)
Fall	1.9 (0.7 to 3.0)	2.5 (1.4 to 3.7)	4.4 (0 to 9.4)	2.6 (1.5 to 3.6)
2014				5.1 (2.5 to 7.6)
Summer	4.7 (2.0 to 7.5)	12.0 (0 to 25.7)	2.6 (0.5 to 4.7)	7.0 (1.6 to 12.4)
Fall	0.6 (0.3 to 0.9)	8.7 (1.4 to 16.0)	0.4 (0.2 to 0.6)	4.4 (0.6 to 8.3)
All	4.5 (3.1 to 5.9)[c]	5.9 (3.9 to 7.8)[d]	4.1 (3.0 to 5.3)	5.1 (4.1 to 6.2)
Summer	5.2 (3.6 to 6.9)[e]	5.9 (3.5 to 8.4)[e]	4.0 (2.8 to 5.1)[e]	5.3 (4.1 to 6.5)
Fall	1.7 (0.9 to 2.6)[f]	5.6 (3.3 to 8.0)[e]	4.7 (1.3 to 8.1)[e]	4.0 (2.7 to 5.3)

[a,b] Statistically significantly different; $P < 0.001$.
[c,d] Statistically significantly different; $P < 0.001$.
[e,f] Statistically significantly different; highest $P = 0.02$.

on the predicted prevalence and EPG of Trichostrongylid-type positive samples were assessed using *post-hoc* pairwise comparison with a level of significance set at $P \leq 0.05$. Similar analyses were completed to estimate differences in *Nematodirus* spp. prevalence and mean EPG among years, seasons, and animal class.

Results

Sample population and number of samples collected

From 2012 to 2014, 3567 fecal samples suitable for analyses were collected from 199 herds. Table 1 shows the number of cows, calves, and replacement heifers sampled by year and season of sample collection. The number of samples collected from each herd ranged from 5 to 57 (median: 20, IQR: 6).

Null-model (unadjusted) prevalence and fecal egg shedding intensity of Trichostrongylid-type eggs and *Nematodirus* spp.

Trichuris spp. was only identified in 7 fecal samples from 4 herds. No *Trichuris* spp. were found in heifers in any of the years and *Trichuris* spp. was also not identified in any of the sampled cattle in 2013. Therefore, subsequent analyses were restricted to Trichostrongylid-type eggs and *Nematodirus* spp. only.

The predicted overall prevalence and mean EPG of Trichostrongylid-type positive samples from the null models were 78% (95% CI: 75% to 82%; Table 2) and 5.1 EPG (95% CI: 4.1 to 6.2; Table 3), respectively. For *Nematodirus* spp., the null-model derived predicted prevalence was 16% (95% CI: 13 to 20; Table 4) while the predicted mean EPG of *Nematodirus* spp. eggs was 0.5 (95% CI: 0.3 to 0.7; Table 5).

Table 4. Results of the GEE models for predicted prevalence [95% confidence interval (CI)] of *Nematodirus* spp. positive samples, accounting for clustering by herd, in 3567 beef cows, calves, and replacement heifers from 199 herds from western Canada sampled between 2012 and 2014, overall (null model) and by year and season of collection (final model).

	Prevalence (95% CI)			
	Cows	Calves	Replacement heifers	All
2012				22 (18 to 26)[a]
Summer	5 (1 to 10)	46 (36 to 56)	4 (0 to 10)	20 (14 to 26)
Fall	25 (0 to 57)	59 (52 to 65)	0	37 (19 to 56)
2013				8 (5 to 11)[b]
Summer	0.5 (0 to 1)	18 (5 to 30)	3 (0 to 6)	5 (2 to 8)
Fall	1 (0 to 3)	25 (12 to 38)	22 (4 to 41)	17 (8 to 26)
2014				12 (6 to 18)[a]
Summer	1 (0 to 2)	20 (0 to 41)	13 (0 to 26)	10 (2 to 19)
Fall	11 (0 to 29)	37 (17 to 56)	0	23 (9 to 37)
All	5 (2 to 9)[e]	34 (28 to 40)[f]	6 (2 to 9)[e]	16 (13 to 20)
Summer	3 (0 to 5)	32 (25 to 39)	5 (1 to 8)	13 (11 to 16)[c]
Fall	14 (1 to 27)	43 (34 to 52)	10 (0 to 27)	22 (16 to 28)[d]

[a,b] Statistically significantly different; highest $P = 0.02$.
[c,d] Statistically significantly different; $P < 0.01$.
[e,f] Statistically significantly different; both $P < 0.01$.

Table 5. Final GEE model for predicted mean eggs per gram (EPG) of feces [95% confidence interval (CI)], accounting for clustering by herd, for *Nematodirus* spp. eggs in 3567 beef cows, calves, and replacement heifers from 199 herds from western Canada sampled between 2012 and 2014, overall (null model) and by season and year of collection (final model).

	Mean EPG (95% CI)			
	Cows	Calves	Replacement heifers	All
2012				0.9 (0.6 to 1.2)[a]
Summer	0.2 (0.0 to 0.4)	1.1 (0.6 to 1.6)	0.1 (0 to 0.3)	0.5 (0.3 to 0.7)
Fall	1.3 (0.1 to 2.5)	3.1 (1.5 to 4.8)	0.0 (0.0 to 0.0)	2.0 (0.8 to 3.1)
2013				0.1 (0 to 0.3)[b]
Summer	0.0 (0.0 to 0.0)	0.1 (0.0 to 0.2)	0.0 (0.0 to 0.0)	0.03 (0.0 to 0.5)
Fall	0.0 (0.0 to 0.0)	0.9 (0.0 to 2.2)	0.2 (0.1 to 0.4)	0.6 (0 to 1.3)
2014				0.3 (0.1 to 0.6)[c]
Summer	0.0 (0.0 to 0.0)	0.5 (0.0 to 1.0)	0.1 (0.0 to 0.2)	0.2 (0.0 to 0.4)
Fall	0.3 (0.0 to 0.8)	1.7 (0.0 to 3.5)	0.0 (0.0 to 0.0)	0.9 (0.03 to 1.9)
All	0.2 (0.1 to 0.3)[f]	1.0 (0.7 to 1.4)[g]	0.1 (0 to 0.2)[f]	0.5 (0.3 to 0.7)
Summer	0.1 (0 to 0.2)	0.6 (0.4 to 0.9)	0.1 (0 to 0.2)	0.3 (0.2 to 0.4)[d]
Fall	0.5 (0.0 to 1.0)	2.8 (1.2 to 4.4)	0.1 (0.0 to 0.4)	1.2 (0.7 to 1.8)[e]

[a,b,c] Statistically significantly different; highest $P = 0.03$.
[d,e] Statistically significantly different; $P < 0.01$.
[f,g] Statistically significantly different; both $P < 0.01$.

Final generalized estimating equation for the predicted prevalence of Trichostrongylid-type eggs in fecal samples

The final GEE model for the predicted prevalence of Trichostrongylid-type egg positive samples included year ($P < 0.001$), season ($P = 0.013$) and a significant interaction between season and animal class ($P = 0.005$) (Table 6).

The predicted prevalence of Trichostrongylid-type egg positive samples differed significantly between years, with a significantly higher predicted prevalence (86%; 95% CI: 82% to 90%) in 2012 than in 2013 (70%; 95% CI: 63% to 77%; $P < 0.01$) and in 2014 (77%; 95% CI: 70% to 84%; $P = 0.02$) (Table 2). There was a significant interaction between season and animal class: the predicted prevalence in cows fell significantly ($P = 0.001$) between summer to fall from 81% to 59% (Table 2). The predicted prevalence in cows in the fall was also significantly lower than the prevalence in both calves and heifers in the fall ($P = 0.000$ and $P = 0.006$, respectively). The predicted prevalence did not differ significantly between animal classes in the summer or in calves and replacement heifers between summer and fall (Table 2).

Final GEE for the predicted mean Trichostrongylid-type eggs per gram of feces

The final GEE model for the predicted mean EPG of Trichostrongylid-type eggs included year ($P = 0.02$), season ($P < 0.01$), and animal class ($P = 0.24$) as fixed effects, and significant interactions between season and animal class ($P < 0.01$) and year and animal class ($P < 0.01$) (Table 7).

The predicted Trichostrongylid-type EPG was significantly higher in 2012 compared to that in 2013 ($P < 0.001$). Cows sampled in the fall had the lowest predicted mean

Table 6. Final binomial GEE model with an exchangeable correlation structure, a logit link function, and robust standard errors, for the predicted prevalence of Trichostrongylid-type and *Nematodirus* spp. eggs in fresh environmental fecal samples collected from 3567 cows, calves, and heifers from 199 herds from western Canada sampled between 2012 and 2014.

	Trichostrongylid-type			*Nematodirus* spp.		
	Odds ratio	*P*-value	95% CI	Odds ratio	*P*-value	95% CI
Year						
2012	Ref			Ref		
2013	0.36	0.00	0.22 to 0.58	0.25	0.00	0.14 to 0.44
2014	0.53	0.02	0.32 to 0.90	0.41	0.02	0.19 to 0.87
Season						
Summer	Ref			Ref		
Fall	0.33	0.00	0.17 to 0.65	2.17	0.01	1.23 to 3.82
Animal class						
Cows	Ref			Ref		
Calves	0.84	0.58	0.45 to 1.56	10.73	0.00	5.00 to 23.04
Replacement heifers	1.12	0.68	0.65 to 1.93	1.11	0.83	0.42 to 2.91
Season by Animal class						
Fall by Cows	Ref					
Fall by Calves	4.52	0.00	1.76 to 11.58			
Fall by Replacement heifers	3.34	0.03	1.13 to 9.90			

CI — confidence interval.

Table 7. Final negative binomial GEE model with an exchangeable correlation structure, a log link function, and robust standard errors, for the predicted mean eggs per gram of Trichostrongylid-type and *Nematodirus* spp. eggs in fresh environmental fecal samples collected from 3567 cows, calves, and heifers from 199 herds from western Canada sampled between 2012 and 2014.

	Trichostrongylid-type eggs			*Nematodirus* spp.		
	Risk ratio	*P*-value	95% CI	Risk ratio	*P*-value	95% CI
Year						
2012	Ref			Ref		
2013	0.47	0.01	0.26 to 0.83	0.01	0.00	0.00 to 0.06
2014	0.68	0.32	0.33 to 1.43	0.22	0.13	0.03 to 1.58
Season						
Summer	Ref			Ref		
Fall	0.40	0.02	0.19 to 0.84	4.31	0.00	2.54 to 7.32
Animal class						
Cows	Ref			Ref		
Calves	1.10	0.78	0.56 to 2.16	4.73	0.00	2.13 to 10.47
Replacement heifers	0.65	0.19	0.35 to 1.23	0.44	0.26	0.11 to 1.84
Season by Animal class						
Fall by Cows	Ref					
Fall by Calves	2.90	0.01	1.28 to 6.53			
Fall by Replacement heifers	3.64	0.01	1.40 to 9.42			
Year by Animal class						
2012 by Cows	Ref			Ref		
2013 by Calves	0.58	0.15	0.27 to 1.22	12.58	0.01	2.14 to 74.08
2013 by Replacement heifers	1.62	0.21	0.78 to 3.41	21.20	0.00	2.97 to 151.40
2014 by Calves	2.90	0.06	0.95 to 8.61	1.75	0.61	0.20 to 15.17
2014 by Replacement heifers	0.91	0.88	0.29 to 2.90	2.29	0.54	0.16 to 33.41

CI — confidence interval.

Trichostrongylid-type egg count at 1.7 (95% CI: 0.9 to 2.6) (Table 3) and cows' predicted mean EPG in the fall was significantly lower than their mean EPG in summer ($P < 0.001$) (Table 3). It was also significantly lower than the predicted mean EPG of calves ($P < 0.001$) and heifers ($P = 0.021$) in the fall and summer ($P < 0.01$ and $P = 0.003$, respectively) (Table 3). There was no statistically significant difference in the predicted mean EPG between seasons in calves or replacement heifers.

In both cows and calves, the predicted mean EPG differed between years. In calves, it was significantly higher in 2012 and 2014 compared to 2013 (both $P < 0.001$); in cows, it was significantly higher in 2012 compared to 2013 and 2014 ($P = 0.01$ and 0.04, respectively). Statistically significant differences are not denoted in Table 3.

Final GEE for the predicted prevalence of Nematodirus spp.

The final GEE model for the predicted prevalence of *Nematodirus* spp. included year ($P < 0.001$), season ($P = 0.008$), and animal class ($P < 0.001$) (Table 6).

The predicted prevalence was significantly higher in 2012 (22%; 95% C: 18% to 26%) than in 2013 (8%; 95% CI: 5% to 11%; $P < 0.001$) or 2014 (12%; 95% CI: 6% to 18%; $P = 0.02$) (Table 4). There were also significantly more ($P < 0.01$) *Nematodirus* spp. positive samples in the fall (22%; 95% CI: 16% to 28%) than in the summer (13%; 95% CI: 11% to 16%). Calves had the highest predicted prevalence of *Nematodirus* spp. at 34% (95% CI: 28% to 40%), which was significantly higher than the predicted prevalence for cows (5%; 95% CI: 2% to 9%; $P < 0.01$) and replacement heifers (6%; 95% CI: 2% to 9%; $P < 0.01$).

Final GEE for the predicted mean *Nematodirus* spp. eggs per gram of feces

The final GEE model for the predicted mean EPG of *Nematodirus* spp. included year ($P < 0.001$), animal class ($P < 0.001$) and season ($P < 0.001$) and a significant interaction term between animal class and year ($P = 0.02$) (Table 7).

The predicted mean *Nematodirus* spp. EPG was significantly higher in 2012 compared to that in 2013 ($P < 0.001$) and 2014 ($P = 0.03$) (Table 5). It was also significantly higher in 2014 than in 2013 ($P = 0.01$). Calves had the highest predicted mean *Nematodirus* spp. EPG at 1.0 (95% CI: 0.7 to 1.4) which was significantly higher than the predicted mean EPG for cows and heifers (both *P*-values < 0.01). Overall, the predicted mean *Nematodirus* spp. EPG was also significantly higher in the fall than in the summer ($P < 0.01$).

In both cows and calves, the predicted mean EPG differed between years. In calves, it was significantly higher in 2012 compared to 2013 ($P < 0.01$) and 2014 ($P = 0.03$); in cows, it was also significantly higher in 2012 compared to 2013 ($P < 0.01$) and 2014 ($P = 0.01$). Statistically significant differences are not denoted in Table 5.

Discussion

There are few studies that report the prevalence or fecal egg count (FEC) intensity of GIN in beef cattle in western Canada. Beef cow-calf production in western Canada encompasses over 70% of all cow-calf beef production in Canada (12).

Trichostrongylid-type egg prevalence was high with 78% of all samples being positive. The prevalence of *Nematodirus* spp. and *Trichuris* spp. was lower, with *Trichuris* spp. being an infrequent finding. This pattern in the prevalence of the morphologically identifiable types of GIN is similar to that described by Jelinski et al (9), who sampled 14 beef cow-calf herds over summer 2014, and is consistent with literature from other parts of the world (11,13).

The prevalence of Trichostrongylid-type egg positive samples found in this study is higher than the prevalence of 63% reported by Polley and Bicks (14) in intensively run cows and their calves in Saskatchewan. The prevalence of 79% in calves reported in this study is also higher than that reported by Colwell et al (15), who sampled weaned beef calves in 2008, 2009, and 2010 in Alberta and found a maximum prevalence of 48%. However, fecal samples from that study had previously been frozen and it is possible that this may have resulted in a reduced egg recovery rate and, therefore, lower prevalence estimation. The prevalence found in calf samples was, however, similar to that in an extensive study of GIN prevalence in weaned beef calves from 291 herds from 24 States in the United States, which found an overall prevalence of 86% (13). The high prevalence of GIN and the moderate egg count intensities seen in cows and replacement heifers were expected based on the GIN epidemiology and recent studies on beef cow-calf herds in Canada (9,16,17).

The prevalence and intensity of GIN based on the GEE were influenced by season and animal class and varied seasonally and annually during the study period. Overall, the prevalence of Trichostrongylid-type eggs in calves and heifers was fairly constant from summer to the fall, but was numerically higher in the fall compared to summer. This is consistent with the known epidemiology of common cattle GIN in temperate cattle producing regions (18–20). Typically, naïve animals start the grazing season in temperate climates with low egg counts and lower prevalence. The GIN prevalence and burden then tend to rise during the grazing season because of pasture contamination and environmental conditions more suitable to L3 survival on pasture. Cows may act as a source of GIN for calves through pasture contamination in the early grazing season. A rise in eggs around calving time, possible emergence of hypobiotic stages, and ingestion of overwintered larvae during the early grazing period likely contributed to pasture contamination in the spring and higher prevalence and EPG in cows compared to fall. Later in the grazing season, GIN prevalence and egg count intensity begin to decrease due to reduced larval development on pasture, effective immunity in adult cattle, and possibly the start of GIN hypobiosis, all of which will reduce the transmission and fecal egg shedding (18–20).

The FEC, while low to moderate in all animal groups, was overall highest in calves and was significantly lower in cows compared to calves and heifers. This is not unexpected as these younger and more naïve animals have yet to develop immunity against GIN (21). In contrast, mature cows would have developed acquired immunity through repeated exposure to GIN and this is probably at least in part reflected by a significant drop in the prevalence and Trichostrongylid-type EPG between summer and fall in that animal class. The Trichostrongylid-type EPG in calves and heifers was less variable. Timing of sampling varied between herds, and sampled herds varied from summer to fall and from year to year with no specific information available in terms of management (e.g., grazing management, stocking density, grazing patterns, type of water source), environmental conditions, or geographic locations (e.g., temperature, precipitation, humidity). These are factors known to affect GIN epidemiology and, therefore, the prevalence and shedding intensity (18,19,22). Also, geographical and temporal diversity in beef cattle GIN infection risk has been demonstrated from Alberta, Canada (23). It is likely that similar differences existed between the herds and years sampled in this study. Annual variations in precipitation and humidity also influence GIN larvae survivability on pasture and the risk of transmission and are likely other possible reasons for some of the yearly differences in prevalence and FEC intensity identified in this study (15).

It is interesting to note that the prevalence of *Nematodirus* spp. was relatively high, particularly in calves. A similar trend

has been seen in the US. Stromberg et al (13) found a prevalence of 18% in samples from 1772 weaned calves 6 to 8 mo of age. *Nematodirus* spp. is a parasite of low pathogenicity unless found in high numbers in young cattle that have not developed immunity (24). There also appears to be an increase in *Nematodirus* spp. found in cattle in the US (25). Reasons for this increase might include the development of anthelmintic resistance in the parasite or the timing of the application of anthelmintic drugs in current management protocols which may favor transmission of *Nematodirus* spp. (25). *Nematodirus* spp. eggs last well unhatched on pasture in the cooler months and only hatch in the warmer weather of the following summer; therefore, the time of peak transmission may be missed by treatment with anthelmintic drugs applied routinely in the spring (25). Monitoring of this parasite may become important to prevent the occurrence of clinical disease in naïve young stock.

There are potentially serious implications for Canadian beef production with changes in GIN prevalence, burden, and the development of anthelmintic resistance. This study provides a baseline for the current prevalence of GIN infection in some western Canadian beef cow-calf herds and complements similar investigations by Jelinski et al (9,17). Unfortunately, specific epidemiological information known to affect GIN burdens in grazing cattle was not collected in this study. Useful information would have included: exact geographical location of samples to account for environmental conditions (humidity, temperature, and precipitation); access to pasture/pasture types, including duration of pasture access prior to sampling; and stocking density/pasture management. The management of beef cow-calf herds in western Canada has changed considerably since Polley and Bickis conducted their study in 1986 (14). Changes in the western Canadian beef cow-calf industry include increasing herd sizes, increasing intensiveness of production systems, later spring calving, and the implementation of low-cost overwintering feeding systems (i.e., swath and bale grazing) (9,12).

Along with the changes in beef cow-cattle management in western Canada, suspected development of anthelmintic resistance and changes in climate also need to be considered for their impact on GIN burdens in beef cattle (2,26,27). The generally high prevalence of GIN infection seen in this study highlights the need for more detailed examination of the epidemiology of GIN on western Canadian beef cow-calf herds, taking into account the factors mentioned. In addition, evaluation of anthelmintic efficacy and a more in-depth understanding of producers' attitudes and management approaches to GIN is needed to better understand how GIN in beef cattle are best managed sustainably in the future.

Samples collected in this study represent convenience samples from beef producers who were motivated to sample these particular herds/animals and who had contact/input from Merck Canada sales representatives. Additionally, different herds with presumably different management styles were sampled in different years. For these reasons, care should be taken when extrapolating the results to a wider population. Furthermore, only limited inferences can be drawn for some results categories because of low sampling numbers in some seasons and animal classes (e.g., heifer samples in the fall of 2014). However, the aim of the study was to describe trends in GIN prevalence and egg count intensities in cow-calf herds in western Canada more broadly, which was achieved with this study.

Limitations in this study and in most studies of GIN in cattle that must be considered include the difficulties in accurately diagnosing "burden," particularly quantifying the intensity of the burden. Fecal egg counts are routinely used for diagnosis; however, they have been shown to be poorly correlated with actual burden in cattle, especially in adult cattle with acquired immunity (28,29). Furthermore, while FEC similarly low to those identified in this study have been associated with reduced production (particularly weight gain) in some studies, it is undetermined what amount of shedding intensity results in production and economic impacts and no conclusions can presently be drawn about the clinical or economic importance of the GIN prevalence and egg shedding intensity identified in this study (30,31). Despite this, FEC are widely accepted as an appropriate way of monitoring GIN infection, particularly until a more effective alternative can be validated (32,33).

In conclusion, this study provides a much-needed summary of gastrointestinal nematode infection in beef cattle from cow-calf herds in western Canada. The findings support the increased susceptibility of calves compared to cows. The high prevalence of positive FECs, when compared to historical data and when considering recent changes in cattle management, climate, and emerging anthelmintic resistance, highlight the need for further investigations. These should include obtaining a better understanding of producers' knowledge and current management practices for GIN in their cattle, and further closing the knowledge gap on GIN prevalence, infection intensity, and species of GIN in western Canadian beef cattle, while also accounting for different management and geographic conditions. This information is necessary in order for more strategic control methods to be developed that maintain efficient production, while limiting the development of anthelmintic resistance.

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