Is the profitability of Canadian tiestall farms associated with their performance on an animal welfare assessment?

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ABSTRACT

In order for dairy producers to comply with animal welfare recommendations, financial investments may be required. In Canada, a new dairy animal care assessment program is currently being implemented under the proAction Initiative to determine the extent to which certain aspects of the Code of Practice are being followed and to assess the care and well-being of dairy cattle on farm. The aim of the current study was to evaluate the association between meeting the proAction animal-based and the electric trainer placement criteria and certain aspects of productivity and profitability on tiestall dairy farms. The results of a previous on-farm cow comfort assessment conducted on 100 Canadian tiestall farms were used to simulate the results of a part of the proAction Animal Care assessment on these farms. Each farm's productivity and profitability data were retrieved from the regional dairy herd improvement associations. Univariable and multivariable linear regressions were used to evaluate the associations between meeting these proAction criteria and the farms' average yearly: corrected milk production, somatic cell count (SCC), calving interval, number of breedings/cow, culling rate, prevalence of cows in third or higher lactation, and margins per cow and per kilogram of quota calculated over replacement costs. The association between milk production and the proAction lameness criterion was moderated through an interaction with the milk production genetic index which resulted in an increase in milk production per year with increasing genetic index that was steeper in farms that met the proAction lameness criterion compared with farms that did not. Meeting the proAction body condition score criterion was associated with reduced SCC and meeting the proAction electric trainer placement criterion was associated with SCC through an interaction with

the farms' average SCC genetic index. The increase in SCC with increasing SCC genetic index was milder in farms that met this criterion compared with farms that did not. Farms that met the proAction electric trainer placement criterion had 4.6% more cows in their third or greater lactation. These results suggest that some associations exist between the productivity of Canadian tiestall farms and meeting several parameters of the proAction Animal Care assessment. Meeting these criteria is unlikely to impose any economic burden to the dairy industry as a whole.

Key words: proAction Initiative, productivity, profitability, welfare, tiestall

INTRODUCTION

Good animal welfare practices have always been a priority for the majority of dairy producers because they respect their animals and because these practices promote good animal health and reassure consumers (McInerney, 1998; De Grassi, 2001). Over the last decades, mandatory legislation, voluntary guidelines, and farm assessment programs have been implemented to regulate and monitor animal welfare on farms (von Keyserlingk et al., 2012; Webster, 2012; Logue and Mayne, 2014). Farm animal welfare is multidimensional, and to monitor its many components as accurately as possible, most farm assessment programs such as Welfare Quality in Europe and Farmers Assuring Responsible Management (FARM) in the United States (Webster, 2012; National Milk Producers Federation, 2016) include animal-, resources-, and management-based measures (Rushen and De Passillé, 2009; Webster, 2012).

In Canada, the Code of Practice for the Care and Handling of Dairy Cattle establishes mandatory requirements and voluntary best practices for the care of dairy animals. The Animal Care portion of the proAction Initiative (DFC-NFACC, 2009; DFC-PLC, 2015) aims to determine the extent to which certain aspects of the Code of Practice are being followed and to assess the care, comfort, and well-being of dairy cattle

Received June 11, 2017.

Accepted November 3, 2017.

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on Canadian dairy farms. Benchmarks have been set for each of the animal-based measures included in this assessment to distinguish between farms that have acceptable practices and farms that need to take corrective actions (DFC-PLC, 2015). Because approximately 70% of Canadian dairy farms use tiestall housing for their lactating animals (AAFC, 2016a), the proAction assessment evaluates the welfare of cows in both loose and tied housing systems, with some specific parameters unique to each type of housing.

Economic arguments can play a role in the degree of compliance with animal welfare standards (Christensen et al., 2012). Sometimes, to comply with the standards, dairy producers are required to make financial investments. These investments may range from none (e.g., to stop tail docking) to very costly if, for example, modifications to the housing system are required. To encourage producers to meet and exceed the animal welfare benchmarks set by welfare assessments, it is essential to understand the links between the cows' well-being, assessed through animal welfare standards, and the farms' productivity and profitability. Some improvements to the animals' welfare (e.g., a reduction in the prevalence of lameness) may increase the farms' profits through reduced cost, increased productivity, or both (Willshire and Bell, 2009). Recently, Bouffard et al. (2017) found that meeting certain recommendations for stall dimensions was associated with reduced prevalence of leg and neck lesions and lameness, which is likely associated with improved production.

Currently, very little scientific information is available on the relationships between farm compliance with animal welfare standards and farm profitability, especially for tiestall dairy farms. The aim of this study was to evaluate potential economic effects of meeting or not some criteria of the Canadian proAction Animal Care assessment in tiestall farms by examining the relationships with milk production, milk quality, reproduction, longevity, and economic margins based on replacement costs. The study also aimed to determine the extent to which meeting one animal-based criteria of proAction was related to meeting other animal-based criteria.

MATERIALS AND METHODS

The institutional research ethics boards and animal care committees of the University of Guelph (Guelph, Ontario, Canada) and the Université Laval (Québec, Québec, Canada) approved all procedures.

Herd and Animal Selection

One hundred Canadian tiestall dairy farms were enrolled in the provinces of Ontario ($n = 40$) and Québec

($n = 60$) as part of a larger cow comfort study (Vasseur et al., 2015). Characteristics of the farms are shown in Table 1. Participation in the study was on a voluntary basis with the initial contact made through mailed letters by the research team or telephone calls by the farm's DHIA advisor. To be eligible to participate in the study, farms had to have a herd size of ≥ 40 Holstein dairy cows in lactation, milk twice a day, not provide outdoor access to lactating animals, have used their current housing system for at least 1 yr, have a mean milk production $\geq 7,000$ kg per cow per year, and be enrolled in their regional DHIA programs (CanWest DHI in Ontario and Valacta Inc. in Québec). We also ensured that the sample of farms was representative of the province in terms of the cows' longevity (measured by the percentage of cows in third or greater lactation and replacement rate; described in Vasseur et al., 2015). The selection process of the farms was not truly random because of these enrollment criteria. However, based on the average number of cows and average corrected yearly milk production, the final sample of farms enrolled was representative of tiestall farms found in the Canadian dairy industry. The average milk production for the farms enrolled in the current study was 9,160 kg and the Canadian DHI reported an average milk production for Holstein cows of 9,300 kg in 2015 (PLQ, 2016). Similarly, the average reported number of cows on Canadian tiestall farms was 58 cows compared with 65 for the farms included in this study (AAFC, 2016b). The average age at first calving, DIM at first breeding, calving interval, and other farms characteristics and productivity parameters evaluated are also similar to current industry averages based on the 2015 DHI reports (PLQ, 2016).

On each farm, 40 focal lactating cows were purposively selected for data collection. The sample of 40 cows per farm was based on the sample size calculation to obtain a reliable lying time estimate, which was the primary target measure for the cow comfort assessment study (Vasseur et al., 2012). The cows were selected to be between 10 and 120 DIM, and the selection reflected the proportion of primiparous and multiparous cows in lactation within the herd, when possible. If a farm did not have 40 milking cows between 10 and 120 DIM, the selection criteria was extended beyond 120 DIM until 40 cows were chosen.

Data Collection and Handling

Each farm was visited between January and December 2011 by a pair of trained observers. A total of 10 observers were trained to collect all the animal- and resource-based measures using strict standard scoring protocols, including written descriptions and pictures,

to ensure high repeatability between all observers (Gibbons et al., 2012; Vasseur et al., 2013; Zaffino Heyerhoff et al., 2014; Nash et al., 2016). Both intra- and inter-observer repeatability were tested multiple times across the data gathering period, and high levels of agreement were achieved (Gibbons et al., 2012; Vasseur et al., 2013). These scoring protocols used for lesions, dirtiness, BCS, and lameness were very similar to the proAction evaluation methods (DFC-PLC, 2015; Vasseur et al., 2015).

Hock and knee lesions were scored using 4-level scoring systems (0 = no swelling or hair loss; 1 = bald area/swelling <1 cm; 2 = lesion on bald area/swelling 1–2.5 cm; 3 = may have bald area/lesion and swelling >2.5 cm), and neck lesions were scored using a 3-level scoring system (0 = no swelling/some broken hair; 1 = no swelling/bald area visible; 2 = broken skin or scab or swelling/may have a bald area), previously reported by Gibbons et al. (2012). For each focal cow, the aim was to evaluate all legs. However, for some animals, only one front (2%) and one back leg (6%) could be evaluated. A cow was considered as having a lesion if at least one leg had a lesion score of 2 or more. Cows with neck score of 2 were considered as having a neck lesion. Dirtiness of the cows' leg, flank, and udder were scored using 4-level scoring systems (0 = contamination of fresh splashes of manure for <50% of the area; 1 = contamination of fresh splashes of manure for >50% of the area; 2 = contamination of dried caked and fresh manure for >50% of the area; 3 = contamination of entire area with dried caked manure; Vasseur et al., 2015; Bouffard et al., 2017). For each focal cow, only the right lower leg and right flank were scored for dirtiness due to time constraints for the assessment. A cow was considered as dirty if she was given a score of 2 or more. The BCS was scored using a simplified validated flowchart with scores ranging from <2 to 5 (Vasseur et al., 2013).

The main objective of this flowchart was to detect the animals considered to be too thin, with BCS ≤ 2 . The farms' lameness prevalence was calculated using the stall lameness score of the 40 focal cows (Leach et al., 2009). Individual video recordings were taken for each focal animal and used, later, to score each animal using a validated in-stall lameness scoring method (Gibbons et al., 2014; Palacio et al., 2017). Video recordings were also used to test inter- and intra-observer repeatability throughout the data collection (Charlton et al., 2016). Briefly, this scoring method consists of evaluating the presence or absence of 4 lameness indicators. When the cow was standing, we recorded weight shifting from one foot to another, uneven weight bearing, and standing on the edge of the stall. When the cow was moved from side to side, the presence or absence of uneven movement was evaluated. If 2 or more indicators were present, the animal was considered lame (Gibbons et al., 2014).

For each animal-based parameter that was evaluated, benchmarks have been set by the proAction Initiative, which discriminates between farms that meet each parameter and farms that need to take corrective actions for each specific proAction criterion (DFC-PLC, 2015). The benchmarks presented in Table 2 represent the excellence target limit for each parameter. The Animal Care part of the proAction Initiative is a new assessment and, at this point in time, only the targets for excellence have been officially announced. The entire Animal Care assessment part of the proAction Initiative contains animal-, management-, and resource/input-based criteria, but because the on-farm comfort assessment did not include all these measures, the current study focused on the animal-based measures (DFC-PLC, 2015). In addition, the electric trainer placement proAction criteria was included because this can greatly affect the cows' comfort in their stalls, and

Table 1. Average characteristics of the 100 dairy tiestall farms enrolled in this study in Ontario and Québec, Canada

Item	n	Mean	SD	Range
No. of milking cows	100	65	17	43–118
Corrected milk production/yr, kg	100	9,160	926	6,478–11,498
SCC/yr ($\times 1,000$)	100	250	96	86–576
Age at first calving, mo	100	26	1.7	23–33
DIM at first breeding	96	82	12	54–119
Calving interval, d	100	429	24	387–488
No. of breeding/cow per yr	94	2.3	0.3	1.6–3.2
% of primiparous in lactation	100	33	8	17–66
% of culling ¹	100	34	10	12–66
% of cows in 3+ lactation	100	40	0.5	17–65
Margin per cow, ² \$/yr	100	5,964	732	3,381–7,545
Margin per kg of quota, ² \$/yr	100	5,904	308	4,407–6,529

¹Left herd for other reasons than sold for milk production.

²Calculated on replacement costs.

Table 2. Benchmarks of the proAction animal- and resource-based criteria included in this study and percentage of farms that met the specific proAction criteria on 100 tiestall farms in Ontario and Québec, Canada

proAction criterion	To meet the criterion	% of farms meeting the criterion
Hock lesions	<10% of cows with lesion	1
Knee lesions	<10% of cows with lesion	9
Neck lesions	<10% of cows with lesion	22
Flank dirtiness	<20% of cows classified dirty	83
Udder dirtiness	<20% of cows classified dirty	97
Leg dirtiness	<20% of cows classified dirty	97
BCS	<5% of cows with BCS ≤ 2	71
Lameness prevalence	<10% of obviously lame cows	27
Trainer placement	100% well placed above the spine	65

is a tool with uncertain usefulness based on published scientific evidence (Bergsten and Pettersson, 1992; Oltenacu et al., 1998). The vertical placement from the chine of the cow and the horizontal placement from the outside edge of the curb of the electric stall trainer of each focal cow were recorded. The placement of the electric stall trainers was recorded as appropriate if the trainer had a high adjustment and was placed above the chine of the animal without touching the cow, when she was standing with her hind leg close to the rear curb of the stall. In addition, farms that did not use electric trainers automatically met the criterion. However, if the electric trainer of one of the 40 focal cows was found to be incorrectly placed, the farm was considered as needing to take corrective action (i.e., not meeting the standard). The conclusions of this study are therefore restricted to the components of the assessment that are listed in Table 2.

Productivity indicators for each farm were based on the data collected by the DHIA programs (CanWest DHI in Ontario; Valacta Inc. in Québec) during the year before the farm visit for the cow comfort assessment study. The productivity indicators were average corrected yearly milk production (kg; corrected at 4% of fat and 3.3% of true protein), average yearly SCC, average calving interval (d), average number of breedings per cow per year, culling rate (%), percentage of cows in third lactation or higher, yearly margin per cow over replacement costs, and yearly margin per kilogram of fat quota over replacement costs. In this study, cows were considered as culled if they left the production herd for any reason other than being sold to another farm for milk production purposes. The farms' overall profitability was assessed using yearly profit margins per cow and per kilogram of production quota based on replacement costs. The profitability margins were calculated for each farm based on the 5-yr average (2010 to 2015) prices for milk solids (\$9.67/kg of fat; \$8.89/kg of proteins; \$1.75/kg of other solids), marketing cost (\$0.14/kg of milk solids), transportation cost (\$2.559/hl), heifer raising cost (\$3,395/animal), cull cow meat

price (\$795/cow), and dead cow removal cost (\$60/cow). The same prices for milk, milk solids, and other costs were used to calculate the margins for all farms across the country. The price of an animal sold for dairy purpose was considered to be equal to the raising cost for a heifer. Because these margins were calculated over the replacements costs, they do not include costs such as feed or veterinary services.

Statistical Analyses

The data were analyzed using Stata 13 statistical software (StataCorp LP, College Station, TX). Descriptive statistics were generated to describe the characteristics of the farms included in this study. The agreement within a farm on meeting or not the proAction criteria evaluated in this study was calculated by adding the number of farms that either met or did not meet the 2 criteria examined divided by the total number of farms. Univariable analyses were also conducted to examine the relationships between the proAction results and the farms' productivity and profitability outcomes.

Multivariable linear regression models were used to analyze the associations between meeting the proAction criteria and the following farm profitability indicators: average corrected yearly milk production (kg), average yearly SCC, average calving interval (d), average number of breedings per cow per year, culling rate (%), percentage of cows in third lactation or higher, yearly margin per cow over replacement costs, and yearly margin per kilogram of quota over replacement costs. Farm characteristics tested in the models were number of milking cows, percentage of primiparous cows in the milking herd, average milk production genetic index (CDN, 2007), average SCC genetic rating (CDN, 2007), age at first calving, and average DIM at first breeding. Genetic index for production and SCC were calculated by the Canadian Dairy Network using the Canadian Test Day Model. For all covariates, an initial cut-off value of $P < 0.2$ in the univariable analysis and a variability of at least 10% for dichotomous covariates

were used as prerequisites to be included in a multivariable model. Backward manual selection model building strategy was used to remove all nonsignificant terms in the models. The significance level was set at $\alpha = 0.05$ for a variable to be retained in the final models. Partial *F*-tests and Akaike and Bayesian information criteria were used to assess the effect of removing categorical variables from the models. Regardless of their statistical significance, confounding variables were retained in the models. Confounding variables were identified based on the causal diagram and if their removal resulted in a change of 20% or greater on the other significant variables coefficients. Interactions between the proAction criteria and the additional covariates tested were investigated based on biological plausibility and kept in the models if statistically significant. The referent for all proAction criteria was that farms did not meet the benchmark of the specific parameter.

For each linear model, the assumption of linearity was assessed visually based on the distribution of the residuals against the continuous predictors included in the model. If nonlinear, the variable was either modeled as a quadratic relationship, if appropriate, based on visual assessment of locally weighed regression curves (Lowess curves) or categorized. Collinearity between predictors was tested using Pearson or Spearman correlations. If 2 variables were found to be highly correlated ($\rho \geq |0.8|$), only the variable with the higher level of interest to the study (linked to animal welfare) was used in the final model. Homoscedasticity and normality of the residuals were assessed visually using the distribution of the standardized residuals against the predicted values of the outcomes and the normal quantile plots, respectively. Outliers and influential observations were identified using visual assessment of standardized residuals, leverage, Cook's distance, and DFITS.

RESULTS

Characteristics of Farms Enrolled

The characteristics of the 100 farms enrolled are presented in Table 1. The number and percentage of farms that met each proAction criterion evaluated in this study are presented in Table 2. No criterion was met by all farms, but the udder and leg dirtiness criteria were met by 97% of farms. In contrast, the hock and knee lesions criteria were met by less than 10% of the farms visited (Table 2). The minimum number of criteria met by a farm was 2, out of a possible 9, and this occurred only on 1 of the 100 farms. The maximum number of criteria met by a farm was 7, and this was achieved on 9 farms.

The relationships between the different proAction criteria is presented in Table 3. This is based on the percentage of farms that either met or did not meet both criteria of each pair of criteria. Two main clusters of criteria were found: one cluster included the 3 measures of cleanliness and BCS, and the second cluster included hock, knee and neck lesions, and lameness. Very strong agreement was found between the hock and knee lesions criteria and between the udder and leg dirtiness ones (Table 3).

Milk Production and Milk Quality

In the univariate analysis, the average yearly corrected milk production was not significantly associated with meeting any of the individual proAction criteria tested. At the multivariable analysis level, meeting the proAction lameness prevalence criterion significantly interacted with the average milk production genetic index to influence the average corrected milk produc-

Table 3. Percentage of farms that either met or did not meet both criteria of each pair of proAction criteria (%) for 100 tiestall farms in Ontario and Québec, Canada

proAction criterion	% of farms with agreement ¹							
	Hock lesions	Knee lesions	Neck lesions	Flank dirtiness	Udder dirtiness	Leg dirtiness	BCS	Lameness prevalence
Hock lesions	—	—	—	—	—	—	—	—
Knee lesions	90	—	—	—	—	—	—	—
Neck lesions	68	68	—	—	—	—	—	—
Flank dirtiness	18	24	34	—	—	—	—	—
Udder dirtiness	4	12	36	84	—	—	—	—
Leg dirtiness	4	12	34	84	96	—	—	—
BCS	28	30	32	66	68	72	—	—
Lameness prevalence	74	76	80	30	28	28	36	—
Trainer placement	36	32	36	62	66	64	62	34

¹The percentage of agreement was calculated by adding the number of farms that either met or did not meet for both proAction parameters divided by the total number of farms.

Figure 1. Effect of the interaction between the milk production genetic index and meeting or not meeting the proAction (PA) criterion for lameness prevalence on average fat- and protein-corrected milk production per year (kg) in 100 tiestall farms in Ontario and Québec, Canada.

tion per year (Table 4). The average yearly corrected milk production increased with increasing milk production genetic index, and this increase was significantly steeper for farms that met the lameness prevalence criterion (Figure 1). An increased average age at first calving was significantly associated with lower average corrected milk production (Table 4).

Yearly average SCC was significantly associated with 4 individual proAction criteria in the univariable statistical analysis. Meeting the proAction criteria for flank dirtiness ($\beta = -51$; 95% CI = -101 to -1 ; $P = 0.047$), BCS ($\beta = -48$; 95% CI = -89 to -7 ; $P = 0.022$), and electric trainer placement ($\beta = -44$; 95% CI = -83 to -4 ; $P = 0.03$) were all associated with lower average SCC by approximately 51,000, 48,000, and 44,000, respectively. In contrast, meeting the neck lesion criterion was significantly associated with a higher SCC of 48,780 ($\beta = 49$; 95% CI = 9 to 88 ; $P = 0.016$). In the multivariable analysis, average SCC genetic rating significantly interacted with the proAction criterion for electric trainer placement to influence the average SCC per year (Table 4). The increase in average SCC with increasing average SCC genetic rating was steeper in farms that did not meet the electric trainer placement criterion compared with farms that did (Figure 2). Meeting the proAction BCS criterion was also significantly associated with a lower SCC (Table 4).

Cow Reproduction

In the univariate analysis, the average calving interval was significantly and positively associated with meeting the proAction criterion for knee lesions with the calving interval 17 d longer in herds that met the

Table 4. Multivariable linear regression models investigating the effects of meeting proAction parameters on the average corrected milk production per year (kg) and the yearly average SCC on 100 tiestall farms in Ontario and Québec, Canada

Model/predictor	n	Mean	SD	Range	β^1	95% CI	P-value
Model 1: corrected milk production/yr, kg							
Age at first calving, d	—	—	—	—	-4.47	-7.360, -1.572	0.003
Milk production genetic index	—	—	—	—	1.64	0.697, 2.578	<0.001
proAction: lameness							
Did not meet	73	9,240	843	6,956–10,818	Referent	—	—
Met	27	8,944	1,108	6,478–11,498	-463.88	-865.688, -62.063	0.024
proAction: lameness $\times$ milk genetic index							
Did not meet $\times$ milk genetic index	—	—	—	—	Referent	—	—
Met $\times$ milk genetic index	—	—	—	—	1.60	0.033, 3.161	0.045
Model 2: average SCC/yr							
Milk production genetic index	—	—	—	—	-0.15	-0.236, -0.059	0.001
SCC ¹ genetic index	—	—	—	—	1,664.03	635.916, 2,692.150	0.002
proAction: BCS							
Did not meet	29	284	98	89–454	Referent	—	—
Met	71	236	92	96–576	-45.58	-83.559, -7.608	0.019
proAction: trainer placement							
Did not meet	35	278	108	86–576	Referent	—	—
Met	65	234	86	97–533	4,373.48	747.908, 7,999.050	0.019
proAction: trainer placement $\times$ SCC genetic rating							
Did not meet $\times$ SCC genetic rating	—	—	—	—	Referent	—	—
Met $\times$ SCC genetic rating	—	—	—	—	-1,479.03	-2,696.750, -261.307	0.018

¹Coefficient.

Table 5. Multivariable linear regression models investigating the effects of meeting proAction parameters on the average number of breedings per cow per year on 95 tiestall farms in Ontario and Québec, Canada

Model/predictor	n	Mean	SD	Range	β^1	95% CI	P-value
DIM at first breeding		—			−0.01	−0.018, −0.007	<0.001
proAction: trainer placement							
Did not meet	31	2.2	0.3	1.8–2.8	Referent	—	—
Met	63	2.4	0.3	1.6–3.2	0.15	0.005, 0.287	0.043

¹Coefficient.

criterion ($\beta = 17$; 95% CI = 0.6 to 34; $P = 0.043$). In the multivariable analysis, none of the proAction criteria were significantly associated with average calving interval.

The average number of breedings per cow per year was negatively associated with meeting the proAction criterion for udder dirtiness ($\beta = -0.66$; 95% CI = -1.16 to -0.16 ; $P = 0.01$) and positively associated with meeting the electric trainer placement criterion ($\beta = 0.18$; 95% CI = 0.03 to 0.34; $P = 0.021$) in the univariable analysis. At the multivariable level, the average number of breedings per cow per year was significantly higher for farms that met the proAction criterion for electric trainer placement and negatively associated with average DIM at first breeding (Table 5).

Cow Culling and Longevity

Meeting each individual proAction criteria was not significantly associated with the culling rate in either the univariable or multivariable analyses.

The percentage of cows in the herd in third or higher lactation was positively associated with meeting the proAction criterion for electric trainer placement in the univariate analysis ($\beta = 3.9$; 95% CI = 0.4 to 7.4; $P = 0.03$). At the multivariate analysis, the percentage of cows in third or higher lactation was significantly higher in farms that met the proAction criterion for stall electric trainer placement and significantly lower with increasing average milk production genetic index (Table 6).

Overall Farm Profitability

Meeting or not meeting the proAction criterion for flank dirtiness was significantly associated with the economic margin over replacement costs per cow in the univariate analysis with higher margins per cow on farms that met the criterion ($\beta = 435$; 95% CI = 56 to 814; $P = 0.025$). In the multivariate analysis, none of the proAction parameters were significantly associated with the margin per cow.

The economic margin over replacement costs per kilogram of fat quota was significantly associated with

proAction criterion for BCS with higher margins per kilogram of quota on farms that met the criterion ($\beta = 172$; 95% CI = 41 to 303; $P = 0.011$). In the multivariate analysis, only the proAction parameter for BCS remained significant in the model.

DISCUSSION

This study focused on the relationship between tiestall farm productivity and profitability and the animal-based components of the proAction animal welfare assessment program (i.e., prevalence of lesions, lameness, dirtiness, and BCS), although the criterion for electric trainer was also included. The results are limited to the criteria evaluated in it and cannot be extrapolated to the other criteria included in proAction Animal Care assessment. Eight of the 9 animal-based criteria included in the proAction assessment were tested. Meeting certain individual animal-based components of the proAction assessment for animal welfare was associated in a complex manner with certain economic measures of farm profitability and performance. However, these results do not allow us to conclude whether or not individual changes made by a farm to meet animal welfare standards will increase or decrease profitability and the

Figure 2. Effect of the interaction between the SCC genetic rating and meeting or not meeting the proAction (PA) parameters for stall electric trainer placement on average SCC per year in 100 tiestall farms in Ontario and Québec, Canada.

Table 6. Multivariable linear regression model investigating the effects of meeting proAction parameters on the percentage of cows in third or greater lactations on 100 tiestall farms in Ontario and Québec, Canada

Model/predictor	n	Mean	SD	Range	β^1	95% CI	P-value
Milk production genetic index		—			−0.02	−0.024, −0.009	<0.001
proAction: trainer placement							
Did not meet	35	38	8	20–53	Referent	—	—
Met	65	42	9	18–65	4.64	1.397, 7.884	0.006

¹Coefficient.

conclusions are limited by the fact that no farms met all of the criteria and that some criteria were met by very few farms.

Overall, the great majority of farms met the criteria associated with BCS and dirtiness, whereas only a small minority met the criteria for lesions and lameness. The dirtiness parameters were the ones met by the highest number of farms. The high percentage of farms that successfully achieved sufficient cleanliness for their milking cows is not very surprising because the relationship between cow cleanliness, udder health, and milk quality is well known (Barkema et al., 1998; Dohmen et al., 2010; Sant'Anna and Paranhos da Costa, 2011). The leg and neck lesions were the parameters that were the least commonly met, which was also expected based on the recent reported prevalence, especially in tiestall farms (von Keyserlingk et al., 2012; Zaffino Heyerhoff et al., 2014; Nash et al., 2016).

The proAction welfare criteria were clustered into 2 groups. The farms' results for the lameness criterion were closely related to their results for the leg and neck lesion criteria and the farms' result for the BCS criterion were closely related to their results for the dirtiness and electric trainer placement criteria. The clustering of these components supports previous findings in tiestall farms, which showed that the prevalence of lameness and leg and neck lesions are all related to stall dimensions (Nash et al., 2016; Bouffard et al., 2017). Similarly, the association between prevalence of hock lesions and lameness prevalence has been previously shown (Zaffino Heyerhoff et al., 2014). Research has also shown a relationship between BCS and lying time, which in tiestall cows may relate to the likelihood of soiling the stalls and, therefore, to dirtiness level of the stalls and animals (Bewley et al., 2010; Westin et al., 2016).

Meeting some individual components of the animal welfare assessment was associated with the measures of farm profitability, but the relationships were often complex. For example, the costs associated with lameness have been estimated many times (e.g., between \$100 and \$500/case depending on the disease), and it is clear that lameness considerably reduces milk production and reproductive success (Willshire and Bell, 2009;

Cha et al., 2010; Huxley, 2013). Reported milk losses for each case of lameness ranges from 270 to 574 kg (Cha et al., 2010; Huxley, 2013; Charfeddine and Pérez-Cabal, 2017). From this, it was expected that farms that met the criterion for lameness prevalence would be more profitable than farms that did not. However, the association between the lameness criterion and average milk production was moderated by the milk production genetic index. This may reflect the difference between tiestall and freestall housing, from which most of the current literature comes. In addition, the unexpectedly high prevalence of tiestall farms that did not meet the lameness proAction criterion may have reduced the likelihood of finding an association with profitability: only about a quarter of the farms met the criterion, which reduced the variability within our sample.

Criteria that were part of the cluster between BCS, dirtiness, and electric trainer placement were more clearly associated with measures of farm profitability. Although our focus was on animal-based components of the proAction Animal Care program, the criterion for correct placement of stall electric trainers was included because it has been previously demonstrated that the use or placement (or both) of electric stall trainers is associated with milk quality, reproductive performance, and culling risk (Oltenacu et al., 1998). In tiestall farms that use them, it is an element to which the cows are exposed at all times, and which can greatly affect cow comfort. In this study, farms that did not use electric stall trainers were included in the same category as farms that had all their electric trainers placed correctly. Meeting the criteria for electric trainer placement and BCS was associated with average SCC. The interaction between electric trainer placement and genetic rating for SCC was interesting: meeting the criterion led to a milder increase in SCC with increasing SCC genetic rating (worst). Meeting the criterion for electric trainer placement was also associated with a slight increase in the number of breedings per cow and a higher percentage of cows in third lactation or higher (cow longevity). The use of electric trainer in tiestall farms has been previously studied and it was concluded that exposure to them increased the incidence of silent heat, clinical mastitis, culling, and decreased reproductive

performance (Oltenacu et al., 1998). These results are similar to the current results in terms of milk quality and cow longevity. Farms that met the BCS criterion had a lower average SCC. An association was also found between meeting the BCS criterion and the margin over replacement cost per kilogram of fat quota. The margin per kilogram of quota was higher by \$172 on farms that had less than 5% of cows with a BCS ≤ 2 . These results were expected based on previous research showing that lower BCS during lactation was associated with the occurrence of mastitis, lameness, and metabolic diseases (Loker et al., 2012; Randall et al., 2015).

The lack of clear relationship between the criteria for leg lesions and farm profitability may reflect the high average prevalence of these lesions and the fact that only a small minority of farms met these criteria, which reduces the variability within our sample. This is particularly true for hock lesions as only one farm met this criterion. Recent research conducted on tiestall farms found an important association between stall dimensions and risk of lesions to the legs and neck (Bouffard et al., 2017). Uncomfortable or inadequate stalls are likely to affect the cows' behavior, which may in turn have an effect on milk production, heat detection, and culling risk as the cows are usually confined to their stall for their entire lactation (Rushen et al., 2007; Tucker et al., 2009).

The use of tiestall housing is often questioned due to the limited freedom of movement it provides to the animals, especially when the animals are not granted access to pasture or an exercise yard (Vučemilo et al., 2012; Popescu et al., 2013). The use of this type of housing is, however, still widespread across the world. In Canada, it is used on approximately 70% of the dairy herds and in the United States, it is the primary housing type for lactating dairy cows on about 39% of the dairy farms (AAFC, 2016a, USDA, 2016). To obtain a sample of farms that were representative of the Canadian dairy industry, farms that allowed pasture access to their lactating cows were excluded from this study. Therefore, the results of this study are limited to farms that do not provide pasture access to their animals.

The animal welfare standards that have been recently introduced in North America and Europe are intended primarily to reassure consumers and food retailers that farm animals are being treated humanely. Their primary purpose is not to improve farm profitability. Nevertheless, demonstrating any existing associations between animal welfare and farm productivity and profitability is likely to be an incentive to encourage dairy producers to invest in animal welfare and comfort improvements. These results demonstrate some links

between particular components of the new Canadian assessment and the likelihood of improved farm profitability. As importantly, these results show that farms that met the criteria included in this study were not suffering from an economic burden due to improved welfare. This study focused on the animal-based measures of the proAction Animal Care program. The complete assessment is composed of a much greater number of components covering subjects such as feeding, handling, and euthanasia. The results of this study are therefore limited to the components studied and cannot be extrapolated to the results of a complete proAction Animal Care assessment. It is also important to remember that the benchmarks used for each criterion included the current study are the current proAction Animal Care thresholds to distinguish excellent farms. Overall, we suggest that meeting the animal-based and electric trainer placement proAction criteria is positive for the dairy farmers because it does not seem to impose any economic burden on them and it gives a more positive image to the entire dairy industry.

CONCLUSIONS

None of the 100 tiestall farms met the 9 criteria included in this study based on the current benchmarks for excellent farms of the proAction Animal Care assessment. The lesions criteria were met by the least farms and the dirtiness criteria were met by the most. Meeting the electric trainer placement and some of the animal-based components of the proAction assessment scheme for animal welfare was associated with some measures of farm profitability or farm performance. This suggests that meeting these specific components is unlikely to impose any economic burden on the Canadian dairy industry as a whole and could potentially financially benefit individual farms, depending on the costs associated with the changes needed to meet the benchmarks of these criteria. Investigating the associations between farm productivity and profitability and cow welfare indicators measured on a continuous basis could help verify the thresholds at which the positive economic effects of cow welfare are maximized.

ACKNOWLEDGMENTS

This research was funded by Agriculture and Agri-Food Canada (AAFC; Ottawa, Ontario, Canada) and Dairy Farmers of Canada (Ottawa, Ontario, Canada) as part of the Dairy Science Cluster initiative, the Fonds Québécois de la Recherche sur la Nature et les Technologies (FQRNT; Québec City, Québec, Canada)–Novalait (Québec, Québec, Canada)–Ministère

de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ; Québec, Québec, Canada), and by Alberta Milk (Edmonton, Alberta, Canada). The authors also thank the students and research coordinators who organized and collected the data: Jenny Gibbons and Gemma Charlton (AAFC, Agassiz, British Columbia, Canada), Clémence Nash and Jessica Zaffino (University of Guelph, Guelph, Ontario, Canada), Véronique Bouffard and François Bécotte (Laval University, Québec City, Québec, Canada), and Laura Solano and Guiherme Bond (University of Calgary, Calgary, Alberta, Canada).

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