Cost of Mastitis in Canadian Dairies

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1 Material & Methods

A cross-sectional study, described in Aghamohammadi et al. [1], was conducted to collect data on factors having an impact on mastitis costs (current expenditures for mastitis treatment and control, and mastitis-associated output losses). Data were collected with the help of a questionnaire consisting of 35 open-ended and multiple-choice questions, mailed in January 2016 to the 374 dairy producers participating in the second phase of the Canadian National Dairy Study [2]. The 374 farms were selected to reflect the proportion of producers by province and of DHI-participating herds according to the official records from the provincial dairy boards (British Columbia, n = 20; Alberta, n = 20; Saskatchewan, n = 10; Manitoba, n = 10; Ontario, n = 133; Québec, n = 121; New-Brunswick, n = 17, Nova-Scotia, n = 18; Prince Edward Island, n = 20, and Newfoundland; n = 5). More details can be found in Aghamohammadi et al. [1], along with the mastitis economic model used, based on the framework proposed by Halasa et al. [6].

Based on data collected from these 374 herds, probability distributions of the various economic model parameters were fit by maximum likelihood estimation [4]. Empirical plots, descriptive statistics, as well as skewness and kurtosis plots (i.e. Cullen and Frey graph, 3) were used to determine the best distributions for each parameter. In order to take into account the uncertainty of the estimated values of kurtosis and skewness from data, a nonparametric bootstrap procedure [5] was performed to obtain boot values of skewness and kurtosis. List of parameters and fitted distributions are given in Table 1.

Table 1: Fitted distribution for economic model parameters.

Parameter	Distribution	Parameters
Milk samples cost for SCM	Gamma	Shape = 0.1; rate = 0.0004
Incidence of CM	Exponential	Rate = 0.04
Proportion of CM receiving treatment	Beta	$\alpha = 0.44$; $\beta = 0.18$
Drug price	Gamma	Shape = 3.27; rate = 0.13
Proportion of clinical mastitis seen by a vet	Beta	$\alpha = 0.2$; $\beta = 3.47$
Veterinary fees for CM	Log-normal	$\mu = 4.6$; $\sigma = 0.41$
Labour time per CM case	Gamma	Shape = 0.15; rate = 0.8
Milk samples cost for CM	Gamma	Shape = 0.24; rate = 0.001
Cost of veterinary advices (udder health)	Gamma	Shape = 0.06; rate = 0.0002
Insurance	Gamma	Shape = 0.12; rate = 0.0009
Proportion of L1 culled due to CM	Beta	$\alpha = 0.22$; $\beta = 15.6$
Proportion of L1 dead due to CM	Beta	$\alpha = 0.05$; $\beta = 20$
Proportion of L2+ culled due to CM	Beta	$\alpha = 0.83$; $\beta = 17.5$
Proportion of L2+ dead due to CM	Beta	$\alpha = 0.26$; $\beta = 46.4$
Rearing costs	Normal	Mean = 2450; SD = 450
Meat value for CM	Logistic	Location = 1109; scale = 165
Salvage value	Gamma	Shape = 0.25; rate = 0.01
Proportion of L1 culled due to SCM	Beta	$\alpha = 0.21$; $\beta = 15$
Proportion of L2+ culled due to SCM	Beta	$\alpha = 0.93$; $\beta = 19$
Meat value for SCC	Log-normal	$\mu = 6.8$; $\sigma = 1.3$
Pre-milking teat disinfection cost	Exponential	Rate = 0.0008
Post-milking teat disinfection cost	Gamma	Shape = 1.79; rate = 0.0009
DCT cost	Gamma	Shape = 1.12; rate = 0.0006
Gloves cost	Exponential	Rate = 0.004
Vaccines cost	Gamma	Shape = 0.26; rate = 0.0006
Treatment time	Gamma	Shape = 5.9; rate = 1.82
Drug withdrawal time	Normal	Mean = 3.2; SD = 0.6
Proportion of cows excluded from bulktank due to high SCC	Beta	$\alpha = 0.17$; $\beta = 2.21$
Number of days before milk is put back in milk tank	Gamma	Shape = 0.6; rate = 0.23
Proportion of milk fed to calves	Beta	$\alpha = 0.17$; $\beta = 0.26$
Number of days out of bulktank due to SCM	Negative binomial	Size = 0.19; $\mu = 30.26$

The economic model described in [1] was applied to 2014 data of DHI-participating herds (N = 8902), with the parameters and their fitted distributions. A total of 1000 data sets were simulated.

For each data set, a stratified random sampling without replacement was used to fill data for herds not participating into DHI, i.e. for which no data were available. Number of participating and non-participating DHI herds are given in Table 2, together with the random samples added. Median values, 2.5 and 97.5 percentiles are then provided for the various costs across the 1000 data sets.

Table 2: Number of DHI-participating herds, number of herds with shipment of milk on August 1, 2015, and number of random samples drawn.

Province	DHI-participating herds	Herds with shipment of milk	Random samples added
New Brunswick	140	206	66
Newfoundland & Labrador	6	32	26
Nova Scotia	143	225	82
Prince Edward Island	110	174	64
Québec	4914	5766	852
Ontario	2613	3834	1221
Manitoba	197	299	102
Saskatchewan	108	163	55
Alberta	384	547	163
British Columbia	287	437	150
Total	8902	11683	2781

Data sets generation and computations were realized in R 3.5.1 [7], and simulation code is available at https://github.com/dhaine/CoMaCAN.

2 Cost Computations Results — DHI herds only

Applying the economic model to Canadian data.

	Total cost	CM cost	SCM cost
2.5%	478615687	158465020	245729884
50%	482802165	161571943	248213139
97.5%	487290439	165265245	250864776

Table 3: Overall Costs — Canada

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	470221483	461806369	460702325	437670860
50%	474287139	465780922	464888804	441857339
97.5%	478525758	469855871	469377078	446345613

Table 4: Overall Costs — Canada — Reduction

The median number of cows per herd is 71.4 (first and third quantiles: 37–81).

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	56238082	161658931	14658605	7032946
50%	57934959	161658931	15201712	7932317
97.5%	59739351	161658931	15829790	8929689

Table 5: Costs — Canada — Milk

	Labour	Product Quality	Prevention
2.5%	7401305	13107140	72462009
50%	7730879	13178467	73001363
97.5%	8088751	13251238	73495115

Table 6: Costs — Canada — Labour, Quality, Prevention

	Culling	Culling (CM)	Culling (SCM)
2.5%	133626791	72859267	59770760
50%	136891363	74909356	61932628
97.5%	140153795	77301211	64390240

Table 7: Costs — Canada — Culling and Mortality

	Total cost	CM cost	SCM cost
2.5%	20300830	6765790	9799480
50%	21100165	7419455	10294336
97.5%	21974151	8132919	10802386

Table 8: Overall Costs — Atlantic

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	19932326	19546192	19519180	18514202
50%	20713864	20320783	20318515	19313537
97.5%	21556702	21127159	21192501	20187523

Table 9: Overall Costs — Atlantic — Reduction

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	2310414	6802084	585086	213253
50%	2646002	6802084	692552	357348
97.5%	2997653	6802084	822645	589487

Table 10: Costs — Atlantic — Milk

The median number of cows per herd in Atlantic provinces is 73.8 (first and third quantiles: 39–86).

	Labour	Product Quality	Prevention
2.5%	291418	87532	3285523
50%	355747	99420	3381501
97.5%	429639	115116	3488968

Table 11: Costs — Atlantic — Labour, Quality, Prevention

	Culling	Culling (CM)	Culling (SCM)
2.5%	5680783	3041850	2439276
50%	6318467	3452898	2866659
97.5%	6972097	3937853	3349333

Table 12: Costs — Atlantic — Culling and Mortality

	Total cost	CM cost	SCM cost
2.5%	227564040	72711192	119752214
50%	229942454	74615679	121234042
97.5%	232461809	76618773	122829583

Table 13: Overall Costs — Québec

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	223712247	219876638	219248362	208556776
50%	226023979	222116792	221626776	210935190
97.5%	228467936	224508301	224146131	213454545

Table 14: Overall Costs — Québec — Reduction

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	25637558	74791234	6668231	3155860
50%	26589700	74791234	6975076	3640904
97.5%	27517708	74791234	7308317	4181930

Table 15: Costs — Québec — Milk

The median number of cows per herd in Québec is 60.4 (first and third quantiles: 35–71).

	Labour	Product Quality	Prevention
2.5%	3407144	12296839	33795970
50%	3612060	12331651	34083305
97.5%	3826494	12379302	34379014

Table 16: Costs — Québec — Labour, Quality, Prevention

	Culling	Culling (CM)	Culling (SCM)
2.5%	61692811	33549798	27467343
50%	63556172	34723111	28831675
97.5%	65626835	36005572	30324772

Table 17: Costs — Québec — Culling and Mortality

	Total cost	CM cost	SCM cost
2.5%	136551348	45116859	69362031
50%	138599837	46768676	70603933
97.5%	140907752	48554414	72106626

Table 18: Overall Costs — Ontario

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	134158624	131759979	131199510	124318576
50%	136133342	133664090	133248000	126367065
97.5%	138329081	135800621	135555915	128674981

Table 19: Overall Costs — Ontario — Reduction

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	15845157	49089057	4087638	1866018
50%	16736882	49089057	4381925	2267392
97.5%	17661554	49089057	4726987	2867958

Table 20: Costs — Ontario — Milk

The median number of cows per herd in Ontario is 70.7 (first and third quantiles: 39–78).

	Labour	Product Quality	Prevention
2.5%	2074262	212349	20912581
50%	2246664	244632	21195727
97.5%	2449636	290493	21499352

Table 21: Costs — Ontario — Labour, Quality, Prevention

	Culling	Culling (CM)	Culling (SCM)
2.5%	38006683	20561301	16747744
50%	39723192	21711073	17982878
97.5%	41509979	22945318	19254444

Table 22: Costs — Ontario — Culling and Mortality

	Total cost	CM cost	SCM cost
2.5%	90729663	30787209	44546900
50%	93048539	32702951	46041080
97.5%	95756537	34776264	47474487

Table 23: Overall Costs — West

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	89061976	87362577	87265467	82811501
50%	91309505	89584082	89584343	85130377
97.5%	93856193	92065183	92292341	87838375

Table 24: Overall Costs — West — Reduction

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	10982487	30976557	2818292	1158219
50%	11931420	30976557	3133463	1581951
97.5%	13040962	30976557	3505510	2232133

Table 25: Costs — West — Milk

The median number of cows per herd in Western provinces is 128 (first and third quantiles: 63–145).

	Labour	Product Quality	Prevention
2.5%	1319965	463670	14048411
50%	1512855	497860	14336951
97.5%	1742906	544360	14643783

Table 26: Costs — West — Labour, Quality, Prevention

	Culling	Culling (CM)	Culling (SCM)
2.5%	25284166	13837467	10855583
50%	27224505	14964960	12226780
97.5%	29217540	16365630	13615915

Table 27: Costs — West — Culling and Mortality

3 Cost Computations Results — DHI and non-DHI herds

	Total cost	CM cost	SCM cost
2.5%	637278759	211806033	326418198
50%	645781152	216939612	331055319
97.5%	655298418	222890725	336262969

Table 28: Overall Costs — Canada — DHI and non-DHI herds

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	626130231	614829903	613380546	582655886
50%	634346730	622868487	621794978	590909584
97.5%	643551372	631891924	631125790	599922568

Table 29: Overall Costs — Canada — Reduction — DHI and non-DHI herds

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	75226732	214742849	19586450	9347114
50%	77792401	216835318	20417245	10657932
97.5%	80846127	219142307	21450639	12172111

Table 30: Costs — Canada — Milk — DHI and non-DHI herds

The median number of cows per herd is 73 (2.5 and 97.5 quantiles: 72.3–73.7).

	Labour	Product Quality	Prevention
2.5%	9899434	15535257	96705894
50%	10360008	15736036	97898694
97.5%	10961517	15965761	99139800

Table 31: Costs — Canada — Labour, Quality, Prevention — DHI and non-DHI herds

	Culling	Culling (CM)	Culling (SCM)
2.5%	178494794	97290651	79665278
50%	183720156	100578025	83124332
97.5%	189197211	104347981	86828981

Table 32: Costs — Canada — Culling and Mortality — DHI and non-DHI herds

	Total cost	CM cost	SCM cost
2.5%	32506679	10955411	15754144
50%	34496817	12146751	16786518
97.5%	36922908	13698051	18106450

Table 33: Overall Costs — Atlantic — DHI and non-DHI herds

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	31937686	31364894	31265676	29675503
50%	33867896	33237077	33224332	31575104
97.5%	36196476	35509229	35616926	33922458

Table 34: Overall Costs — Atlantic — Reduction — DHI and non-DHI herds

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	3721068	10655423	925146	332976
50%	4322845	11071311	1130429	573073
97.5%	5177667	11534374	1398517	1075647

Table 35: Costs — Atlantic — Milk — DHI and non-DHI herds

The median number of cows per herd in Atlantic provinces is 75.7 (2.5 and 97.5 percentiles: 73–78.7).

	Labour	Product Quality	Prevention
2.5%	459030	130826	5261193
50%	577438	158615	5538387
97.5%	733558	196781	5841566

Table 36: Costs — Atlantic — Labour, Quality, Prevention — DHI and non-DHI herds

	Culling	Culling (CM)	Culling (SCM)
2.5%	9145883	4879683	3893756
50%	10345216	5648202	4667610
97.5%	11889239	6659704	5754190

Table 37: Costs — Atlantic — Culling and Mortality — DHI and non-DHI herds

	Total cost	CM cost	SCM cost
2.5%	266134159	85238082	140170383
50%	269852514	87538788	142264999
97.5%	273784126	90050993	144541220

Table 38: Overall Costs — Québec — DHI and non-DHI herds

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	261639844	257163990	256420378	243968862
50%	265226158	260622692	260081761	247524037
97.5%	269032032	264307346	263943723	251348444

Table 39: Overall Costs — Québec — Reduction — DHI and non-DHI herds

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	29914793	87102626	7788689	3658329
50%	31201650	87742284	8190273	4280455
97.5%	32387015	88547989	8586509	4927954

Table 40: Costs — Québec — Milk — DHI and non-DHI herds

The median number of cows per herd in Québec is 60.4 (2.5 and 97.5 percentiles: 60–61).

	Labour	Product Quality	Prevention
2.5%	3997743	14292882	39546457
50%	4240277	14467092	39983072
97.5%	4517423	14671331	40470285

Table 41: Costs — Québec — Labour, Quality, Prevention — DHI and non-DHI herds

	Culling	Culling (CM)	Culling (SCM)
2.5%	72173750	39249285	32166927
50%	74547917	40743805	33820036
97.5%	77195548	42486005	35578139

Table 42: Costs — Québec — Culling and Mortality — DHI and non-DHI herds

	Total cost	CM cost	SCM cost
2.5%	198511899	65697105	101055218
50%	203327212	68604406	103562410
97.5%	208931002	72021923	106801781

Table 43: Overall Costs — Ontario — DHI and non-DHI herds

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	195040185	191522249	190750766	180772166
50%	199721479	196122015	195474172	185384728
97.5%	205157930	201401565	200921886	190680967

Table 44: Overall Costs — Ontario — Reduction — DHI and non-DHI herds

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	23119071	70739785	5956126	2705604
50%	24559959	72002466	6437799	3329140
97.5%	26195157	73356271	7006076	4260147

Table 45: Costs — Ontario — Milk — DHI and non-DHI herds

The median number of cows per herd in Ontario is 70.7 (2.5 and 97.5 percentiles: 69.4–72.1).

	Labour	Product Quality	Prevention
2.5%	3028378	307539	30411624
50%	3288773	358951	31095671
97.5%	3667895	432668	31858063

Table 46: Costs — Ontario — Labour, Quality, Prevention — DHI and non-DHI herds

	Culling	Culling (CM)	Culling (SCM)
2.5%	55524262	29999188	24366732
50%	58251872	31853840	26327722
97.5%	61563686	34035123	28605310

Table 47: Costs — Ontario — Culling and Mortality — DHI and non-DHI herds

	Total cost	CM cost	SCM cost
2.5%	132587655	45348164	65395809
50%	138009210	48474511	68225299
97.5%	144159788	52313030	71704162

Table 48: Overall Costs — West — DHI and non-DHI herds

	Total cost (-10% CM)	Total cost (-20% CM)	Total cost (-10% SCC)	Total cost (-20% SCC)
2.5%	130157409	127688614	127599850	121176134
50%	135425898	132839254	132858330	126251158
97.5%	141421192	138599153	138985504	132288338

Table 49: Overall Costs — West — Reduction — DHI and non-DHI herds

	Milk yield reduction (CM)	Milk yield reduction (SCM)	Discarded milk (CM)	Discarded milk (SCM)
2.5%	16099628	44574379	4147797	1665917
50%	17661040	45965401	4623057	2338555
97.5%	19732421	47515980	5323717	3402129

Table 50: Costs — West — Milk — DHI and non-DHI herds

The median number of cows per herd in Western provinces is 128.1 (2.5 and 97.5 percentiles: 124.7–132.2).

	Labour	Product Quality	Prevention
2.5%	1933393	657065	20514950
50%	2237082	739179	21229382
97.5%	2666620	847785	22141851

Table 51: Costs — West — Labour, Quality, Prevention — DHI and non-DHI herds

	Culling	Culling (CM)	Culling (SCM)
2.5%	37183483	20075238	15908002
50%	40303203	22163367	18089225
97.5%	43872053	24613301	20548532

Table 52: Costs — West — Culling and Mortality — DHI and non-DHI herds

References

[1] M. Aghamohammadi, D. Haine, D. F. Kelton, H. W. Barkema, H. Hogeveen, G. P. Keefe, and S. Dufour. Herd-level mastitis-associated costs on Canadian dairy farms. *Frontiers in Veterinary Science*, 5:100, 2018. doi: 10.3389/fvets.2018.00100. URL https://www.frontiersin.org/article/10.3389/fvets.2018.00100. 3

[2] E. Belage, S. Dufour, C. Bauman, A. Jones-Bitton, and D. Kelton. The Canadian National Dairy Study 2015—Adoption of milking practices in Canadian dairy herds. *Journal of Dairy Science*, 100(5):3839–3949, 2017. doi: https://doi.org/10.3168/jds.2016-12187. URL http://www.sciencedirect.com/science/article/pii/S0022030217302321. 3

[3] A. Cullen and H. Frey. *Probabilistic Techniques in Exposure Assessment*. Plenum Publishing Co., 1st edition edition, 1999. 3

[4] M. Delignette-Muller and C. Dutang. fitdistrplus: An R package for fitting distributions. *Journal of Statistical Software*, 64(4):1–34, 2015. doi: 10.18637/jss.v064.i04. URL https://www.jstatsoft.org/v064/i04. 3

[5] B. Efron and R. Tibshirani. *An Introduction to the Bootstrap*. Chapman & Hall, 1st edition edition, 1994. 3

[6] T. Halasa, K. Huijps, O. Østerås, and H. Hogeveen. Economic effects of bovine mastitis and mastitis management: A review. *Veterinary Quarterly*, 29(1):18–31, 2007. doi: 10.1080/01652176.2007.9695224. URL https://doi.org/10.1080/01652176.2007.9695224. 3

[7] R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria, 2018. URL http://www.R-project.org. 4