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Réforme des vaches laitières au Québec

par

Denis HAINE

Département de sciences cliniques
Faculté de médecine vétérinaire

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RÉSUMÉ

Il existe plusieurs moyens d'augmenter la rentabilité d'une exploitation laitière. Parmi celles-ci, la réforme peut avoir un effet sur la production moyenne du troupeau et par conséquent sur les coûts de production de par la modulation de la structure du troupeau qu'elle entraîne. Afin de déterminer une rentabilité optimale des troupeaux, il est donc important de quantifier la réforme et de comprendre les mécanismes qui amènent à réformer un animal. Cette thèse a pour objectif principal de décrire la réforme dans les troupeaux laitiers du Québec. Plus précisément, elle vise à quantifier le taux de réforme, à explorer la relation entre le troupeau, le taux de réforme et le risque individuel de réforme, à déterminer l'effet causal de la mammite clinique sur la réforme, et à identifier les critères de décision utilisés lors de la réforme par les producteurs et les différents intervenants à la ferme.

Une étude rétrospective longitudinale a été menée à partir des informations de santé et de production des vaches des troupeaux laitiers du Québec (Canada). Dix années de données, entre 2001 et 2010, ont été utilisées afin de déterminer des profils de troupeau et leurs taux de réforme, et un éventuel lien entre ceux-ci. L'influence du troupeau sur le risque individuel de réforme d'une part, et l'effet causal de la mammite clinique sur la réforme d'autre part, ont été explorés respectivement par analyse contextuelle et à l'aide d'un modèle marginal structural. Les critères de décision de réforme communs entre les producteurs, vétérinaires et autres conseillers ont été identifiés grâce à la méthodologie Q, qui permet de révéler la structure décisionnelle des individus.

Cette étude a permis de quantifier un taux de réforme moyen de 32% sur les dix années de suivi de la cohorte, avec des variations importantes entre troupeaux. Il n'a pas été possible de déterminer des profils spécifiques de troupeaux en fonction d'un ensemble de caractéristiques liées à leurs performances de reproduction, de production, à leur gestion et indicateurs de santé. Il est, par contre, possible de les distinguer en fonction de certaines caractéristiques prise une à une et d'y associer le taux de réforme, notamment pour la gestion, la reproduction et la quantité de lait produite. Ces caractéristiques peuvent servir de variables contextuelles dans des analyses multiniveaux.

Un effet contextuel du troupeau est présent dans le risque individuel de réforme, mais limité. Il résulte essentiellement de la pression exercée par les primipares arrivant dans le troupeau. Le risque de réforme dû à la mammite clinique, évalué dans le cadre contrefactuel d'une étude longitudinale où l'exposition est dépendante du temps, est comparable entre primipares et multipares. Pour ce risque, la production laitière a moins d'influence chez les primipares que chez les multipares.

Les producteurs et leurs conseillers se réfère à un cadre de décision commun pour réformer une vache, se référant essentiellement à la santé mammaire de la vache et à sa production de lait. Le taux de réforme du troupeau n'intervient pas dans la décision de réformer une vache particulière.

Mots clés: réforme, vache laitière, survie, biais, prise de décision.

ABSTRACT

There are several ways to increase the profitability of dairy farms. Among them, culling can affect the average herd production and therefore the costs of production, by modifying the herd structure. In order to determine an optimal herd profitability, it is important to quantify the culling rates and to understand the mechanisms leading to the culling of an animal. The main objective of this thesis is to describe culling in Québec dairy herds. Specifically, it aims to quantify the culling rates, to explore relationship between the herd, the culling rate, and the individual culling risk, to determine the causal effect of clinical mastitis on culling, and to identify the decision-making criteria used by producers and farm advisers.

A retrospective longitudinal study was conducted on health and production data from cows in dairy herds from Québec, Canada. Ten years of data, between 2001 and 2010, were used to determine herd profiles and their culling rates, and their potential relationship. Herd influence on individual culling risk and the causal effect of clinical mastitis were explored respectively by contextual analysis and by using a marginal structural model. Shared criteria on culling decisions held by dairy producers, veterinarians and other advisers were identified with the help of the Q-methodology, which provides a means to reveal the decision structure of individuals.

This study quantified an average culling rate of 32% based on ten years of follow-up, with significant variations between herds. Specific herd profiles according to a set of characteristics related to their reproductive and production performances, management and health indicators could not be determined. It is however possible to distinguish herds against certain unique feature taken one by one and to relate it to the culling rate, including herd management, reproduction performances, and milk production. These indicators can be considered as contextual variables in multilevel analyses.

A herd contextual effect is present in the cow culling risk, but limited. It is mainly due to the pressure of heifers coming into the herd. Culling risk due to clinical mastitis, considered in the counterfactual framework of a longitudinal study where exposure is time-varying, is comparable between primiparous and multiparous cows. For this risk, dairy production has less influence in primiparous that in multiparous cows.

Producers and their advisers share a common framework for culling decision-making, referring essentially to cow's udder health and her milk production. Herd culling rate is not involved in the decision to cull a specific cow.

Keywords: culling, dairy cow, survival, bias, decision-making.

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π	$\simeq 3.14\ldots$
σ_z^2	Variance du troupeau
ABHB	Acide β-hydroxybutyrique
AGNE	Acide gras non estérifié
CCS	Comptage des cellules somatiques
CI	Intervalle de confiance (Confidence Interval)
CM	Mammite clinique (Clinical Mastitis)
COD	Ovaires kystiques (Cystic Ovaries Disease)
CPU	Processeur central (Central Processing Unit)
CR	Taux de réforme (Culling Rate)
CR60	Taux de réforme endéans les 60^{ers} jours en lait
CrI	Intervalle de crédibilité (Credible Interval)
DA	Déplacement de caillette (Displaced Abomasum)
DAG	Graphe orienté acyclique (Directed Acyclic Graph)
DHI	Agence de contrôle laitier (Dairy Herd Improvement association)
DIM	Jours en lait (Days In Milk)
DS60	Vente au lait endéans les 60^{ers} jours en lait
DSS	Système d'aide à la décision (Decision Support System)
EC2	Elastic Compute Cloud
FMV	Faculté de médecine vétérinaire
GEE	Équation d'estimation généralisée (Generalized Estimating Equation)

HR Rapport de risque (Hazard Ratio)

ICC Corrélation intraclasse (Intra-cluster Correlation Coefficient)

IPTW Pondération par probabilité de traitement inverse (Inverse Probability of Treatment Weighting)

L1 Taure

L2+ Parités 2 et plus

L3+ Parités 3 et plus

LTS Long Term Support

MAP Minimum Average Partial

MCMC Monte Carlo par chaîne de Markov (Markov Chain Monte Carlo)

MET Endométrite

MF Fièvre de lait (Milk Fever)

MFA Analyse factorielle multiple (Multiple Factor Analysis)

MOR Odds ratio médian (Median Odds Ratio)

MSM Modèle structural marginal (Marginal Structural Model)

OR Rapport de cote (Odds Ratio)

PCA Analyse en composantes principales (Principal Component Analysis)

PCV Variation proportionnelle de la variance (Proportional Change in Variance)

RP Rétention placentaire (Retained Placenta)

RPO Prime à la rétention (RPO)

SCC Comptage des cellules somatiques (Somatic Cell Count)

SD Écart type (Standard Deviation)

VSS Very Simple Structure

WAIC Watanabe–Akaike Information Criterion

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CHAPITRE 1

INTRODUCTION

L'objectif de la plupart des producteurs laitiers est d'obtenir un revenu raisonnable de son travail. Comme entrepreneur, il est donc au défi de produire au meilleur coût et donc d'atteindre une certaine efficacité technique et financière, et ce même dans le cadre d'une gestion de l'offre qui se propose de leur offrir une rémunération équitable. Différentes stratégies sont possibles pour améliorer la rentabilité de l'exploitation laitière :

— réaliser des économies d'échelle. Mais les frais fixes sont importants en production laitière et l'augmentation de la taille du troupeau a un impact réduit sur les charges de structure ;

— produire plus de lait, pour autant que les profits générés par l'augmentation de la production soient supérieurs aux dépenses additionnelles requises en intrants (fourrages, concentrés) pour induire cet accroissement de production ;

— réduire les intrants, c'est-à-dire maîtriser ou réduire les dépenses d'alimentation (par exemple en mettant les vaches au pâturage) tout en produisant son quota.

De ces trois stratégies, la seconde est la plus pertinente à mettre en pratique, alors que la vente du lait représente 89% des revenus des fermes laitières québécoises (Pellerin et al., 2008). La production moyenne par vache est dès lors un élément déterminant pour la rentabilité de la ferme laitière. Cette production moyenne, et donc les coûts de production, sera affectée par l'alimentation, la gestion du troupeau et les politiques d'élevage et de réforme.

Une vache pourrait vivre 20 ans avant de mourir de vieillesse. Pourtant, peu d'entre elles demeureront dans le troupeau aussi longtemps. Dans les troupeaux laitiers canadiens, 30 à 40% des vaches sont réformées chaque année (Gouvernement du Canada, 2015), à un âge moyen variant entre 5 et 6 ans. La valeur des vaches d'un troupeau subit une dépréciation avec l'âge et les différentes maladies survenant au cours de la vie de l'animal. Dès lors, les producteurs doivent se séparer de certaines vaches parce qu'elles ne sont plus profitables, ou parce que d'autres vaches, généralement plus jeunes, le sont plus. C'est la vie utile de la vache, plus courte que sa longévité potentielle de 20 ans car une décision économique de la part du producteur est prise à son égard (Fetrow et al., 2006). Cette décision économique de réforme prend en compte des facteurs intrinsèques à la vache (santé, production de lait, statut reproducteur) et des facteurs extrinsèques, tels que la disponibilité d'animaux de remplacement, la capacité de la salle de traite, la disponibilité de terres, les prix offerts, etc. (Dohoo et al., 1993)

Réformer un animal a aussi un coût, appelé coût de renouvellement, qui correspond au rapport entre d'une part l'amortissement de la différence entre la valeur de la génisse de remplacement et celle de la vache de réforme, et d'autre part la production de cette vache avant sa réforme. Ce coût de renouvellement peut être minimisé en diminuant le coût de production d'une génisse d'une part, et d'autre part en augmentant la durée de vie productive des vaches. La longévité influence donc ces coûts de renouvellement : une augmentation de 5% du taux de réforme augmente ces coûts de 20% par litre de lait produit (Seegers et al., 1994). Il ne faut cependant pas perdre de vue les bénéfices associés à la réforme, par le retrait d'animaux moins rémunérateurs et leur remplacement par d'autres plus avantageux.

La réforme, par la modulation de la structure du troupeau qu'elle entraîne, aura donc un effet sur la production moyenne du troupeau et par conséquent, sur les coûts de production. Pourtant, on observe des taux de réforme au Québec et au Canada qui sont élevés, dépassant souvent les 30%. On constate également de larges variations entre troupeaux de l'incidence de maladies, ainsi que de leur environnement socio-économique. Ces variations peuvent potentiellement influencer le processus de décision de réforme. Il est donc important de comprendre les mécanismes de la réforme, surtout dans un contexte particulier où existe la gestion de l'offre. Combien de vaches sont réformées ? Lesquelles ? Pourquoi et comment sont-elles réformées ? Ce sont tous des éléments à jauger si on veut établir une stratégie de réforme et de gestion du troupeau globale permettant de déterminer une rentabilité optimale des troupeaux québécois.

Au préalable, la réforme devra être définie et ses liens avec la santé et la longévité précisés. La réforme sera aussi remise dans le contexte général du processus de décision.

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CHAPITRE 2

RECENSION DES ÉCRITS

L'objectif de cette recension des écrits est de synthétiser les connaissances relatives à la réforme de la vache laitière, de situer cette pratique dans le cadre de la gestion de l'entreprise laitière et de relever les faiblesses dans les connaissances actuelles. La réforme sera d'abord définie puis ces modalités présentées, qui permettront de cerner la complexité reliée au remplacement des animaux. Enfin la réforme sera remise dans le contexte global de la ferme laitière.

2.1 Définition et terminologies

Une vache laitière génère un revenu au producteur laitier à partir de sa production de lait, des veaux produits et de la valeur de sa carcasse à la fin de sa vie productive. Le produit de ces revenus peut être diminué, conduisant à la sélection d'animaux inférieurs (et parfois surnuméraires) et à leur retrait du troupeau : la réforme.

Une vache réformée est une vache écartée du troupeau en raison de sa vente aux fins d'abattage, aux fins d'engraissement, pour continuer sa vie productive dans un autre troupeau ou en raison de son décès (Fetrow et al., 2006). Cette vache réformée est la plupart du temps remplacée par une plus jeune, généralement une taure prête à vêler, si l'on assume une taille de troupeau constante ou en expansion (Hadley et al., 2006). Remplacement et réforme sont alors équivalents.

L'intensité de la réforme peut être quantifiée comme un taux d'incidence : le nombre de vaches réformées pendant une certaine période, divisé par la population à risque d'être réformée pendant cette même période. Il n'est cependant pas toujours facile de suivre la cohorte d'animaux nécessaire pour déterminer cette incidence. De plus ce suivi peut prendre du temps, rendant cette façon de calculer le taux de réforme trop historique pour une gestion quotidienne de l'exploitation laitière (Fetrow et al., 2006). L'incidence de réforme est donc essentiellement utilisée en recherche.

Le taux de renouvellement du troupeau simplifie la détermination du dénominateur dans la formule précédente en faisant une approximation du nombre de vaches à risque à partir du nombre moyen d'animaux présents dans le troupeau pour la période d'intérêt (Smith et al., 2000). Cette estimation est couramment retrouvée dans les logiciels de gestion utilisés en ferme.

Deux autres expressions de la longévité sont aussi communément rencontrées en production laitière : la proportion de vaches en 3^{e} lactation et plus, et l'âge moyen du troupeau. Ces dernières représentent cependant la même réalité. Même si la conversion mathématique n'est qu'approximative, le taux de remplacement équivaut à peu près à la proportion de primipares, et la durée de vie après le 1er vêlage correspond sensiblement à $^{1}/_{\text{taux de remplacement}}$ (De Vries, 2013).

Taux de réforme

Un taux de réforme dit « idéal » a été déterminé par modélisation et se situerait entre 25 et 30% (Allaire, 1981 ; Congleton Jr. et al., 1984 ; Demeter et al., 2011 ; Kristensen, 1987 ; Rogers et al., 1988 ; Van Arendonk, 1985). Pourtant, les taux moyens de réforme rapportés dans la littérature, notamment en Amérique du Nord, dépassent fréquemment les 30% (De Vries et al., 2010 ; Dechow et al., 2008 ; Fetrow, 1987 ; Gröhn et al., 2005 ; Oler et al., 2012 ; Radke et al., 2000 ; Rajala-Schultz et al., 1999a ; Smith et al., 2000). Il est souvent conseillé de diminuer ce taux de réforme, notamment dans la littérature technique.

Il est cependant difficile de concevoir qu'il n'y aurait qu'un seul taux de réforme idéal valable pour tous les troupeaux, tout au long de l'année. Le taux de réforme est le résultat d'une série de décisions prises tous les jours pour chaque vache. La réforme étant un évènement inévitable permettant le retrait d'animaux malades et non rentables et l'ajout d'autres supérieurs génétiquement et économiquement, chaque troupeau a un taux de réforme qui lui est « optimalement » propre et fonction de sa dynamique (Rapnicki et al., 2003). Si la décision de réforme est optimale pour chaque vache du troupeau, alors le taux de réforme de ce troupeau est idéal pour lui. Le taux de réforme doit donc être pris en considération avec les autres données du troupeau (santé, reproduction, production). Par exemple, un taux élevé peut être causé par un problème de santé ou un élevage important de taures, un taux bas peut indiquer une difficulté à remplacer les animaux ou tout simplement un troupeau en expansion. Le processus de décision menant à la décision de réformer une vache s'avère donc complexe, comportant aussi bien des éléments individuels (production de la vache, stade de lactation, statut reproducteur, âge, valeur génétique, problèmes de santé) que de troupeau (sa dynamique à court et long terme, les besoins de production, la disponibilité d'animaux de remplacement, le prix du lait et des animaux réformés). La combinaison de différents éléments, hiérarchiques, économiques, voire sociaux et même subjectifs, forme un système complexe qui peut être difficilement appréhendé par la cognition humaine (Emmeche, 1997 ; Simon, 1962). Ces composantes peuvent ainsi représenter des pièges à l'interprétation et à la compréhension du processus de réforme, et à l'emploi du taux de réforme dans la gestion de l'exploitation laitière.

2.2 Les pièges de la réforme

2.2.1 Réforme et santé

Le taux de réforme est encore souvent utilisé comme un indicateur de santé du troupeau, avec le corollaire qu'un taux élevé signale un problème de gestion du troupeau (Eicker et al., 2003). L'analogie avec l'espérance de vie humaine est tentante. En effet, l'amélioration des conditions de vie humaine (meilleurs revenus, salubrité, nutrition, éducation, hygiène publique, soins médicaux et modifications de caractéristiques individuelles, comme l'arrêt de la cigarette ou une alimentation réduite en gras) ont permis un allongement spectaculaire de l'espérance de vie un peu partout dans le monde (Oeppen et al., 2002). L'espérance de vie humaine est un indicateur synthétique de la mortalité survenant dans une population ; une mesure plus intuitive que le taux de mortalité ne peut l'être lui-même. Or la mortalité dans les troupeaux laitiers est plutôt faible, tournant aux alentours de 5–6% par année (Alvåsen et al., 2012 ; Gouvernement du Canada, 2015 ; Pinedo et al., 2010a). C'est-à-dire que, pour un troupeau de cent vaches qui en réforme trente par an, cinq vaches décèdent à la ferme et vingt-cinq, soit 83%, sortent « vivantes » du troupeau. Celles-ci, qui représentent donc la majeure partie des vaches réformées, quittent la ferme suite à une décision prise par le producteur pour son animal, décision qui est en soi un acte économique car la vache est vendue (à une autre exploitation laitière ou à un abattoir). D'autre part, on peut noter que le taux de réforme étant par nature une vision rétrospective du troupeau, il est dès lors délicat de l'utiliser pour identifier des problèmes de gestion ou des problèmes de santé actuels, l'alarme déclenchée par un taux trop élevé arrivant trop tard (Eicker et al., 2000). Par contre, cet aspect rétrospectif pourrait être utilisé afin de savoir si les animaux réformés l'ont été trop tôt ou trop tard (Rapnicki et al., 2003).

Une autre manière d'évaluer la réforme est de l'appréhender selon les raisons qui ont amené au départ de la vache, soit volontaire ou involontaire (Dohoo et al., 1993 ; Weigel et al., 2003). Une réforme volontaire est une vache considérée comme mauvaise productrice ou vendue à un autre troupeau (afin qu'elle y génère des revenus : produire du lait, des veaux, des embryons) ; une réforme involontaire concerne des vaches forcées de quitter le troupeau à cause de mammite, boiterie, infertilité, maladies, décès, etc. Cependant, à l'exception du peu d'animaux qui meurent en ferme, toute réforme peut être considérée comme volontaire car elle résulte d'une décision motivée du producteur. Face à un animal malade, le producteur doit prendre une décision. Bien qu'il n'aie pas choisi d'avoir une vache avec un taux élevé de cellules somatiques ou non gestante par exemple, il pourrait en déférer le moment de la réforme. La vache souffrant de mammite pourrait ne pas être réformée mais traitée médicalement, faire l'objet d'une traite différée, etc. La vache non gestante pourrait encore être inséminée une nouvelle fois. L'animal réformé aurait donc pu l'être plus tôt ou plus tard. D'autres considérations que le seul statut de santé de l'animal doivent donc intervenir dans la prise de décision. Ces classifications des réformes comme volontaires ou involontaires ont donc été critiquées avec raison car elles ne reflètent pas la réalité de la décision de réforme et n'informent pas précisément sur les raisons de la réforme, qui sont généralement multiples (Bascom et al., 1998 ; Dohoo et al., 1993 ; Fetrow, 1987).

Le risque de réforme varie grandement entre vaches d'un même troupeau. Mais une vache gestante, jeune, ayant une bonne production laitière et aucun problème de santé sera moins susceptible d'être réformée (De Vries et al., 2010 ; Gröhn et al., 1998 ; Rajala-Schultz et al., 1999a,c ; Seegers et al., 1998). On peut facilement reconnaître que les problèmes de santé sont des facteurs de risque pour la réforme d'une vache. Cependant ce risque varie selon la condition de santé envisagée, et les troubles métaboliques et de la reproduction ont un effet plus nuancé sur la réforme (Beaudeau et al., 2000). Ainsi, une vache gestante a de trois à sept fois moins de chance d'être réformée (De Vries et al., 2010 ; Gröhn et al., 1998 ; Pinedo et al., 2014 ; Rajala-Schultz et al., 1999b ; Schneider et al., 2007), mais elle sera à risque accru d'être réformée si elle est devenue gestante tardivement lors de sa lactation précédente, et particulièrement si son insémination fécondante a eu lieu plus de 300 jours après le dernier vêlage (Pinedo et al., 2010b).

Les dystocies (Beaudeau et al., 1995 ; Oltenacu et al., 1990 ; Rajala-Schultz et al., 1999b), les avortements (Beaudeau et al., 1994, 1995 ; Bell et al., 2010) et les pathologies de la glande mammaire (c'est-à-dire mammites et blessures des trayons ; Archer et al., 2013 ; Beaudeau et al., 1994, 1995 ; Cha et al., 2013 ; Gröhn et al., 1998, 2005 ; Neerhof et al., 2000 ; Rajala-Schultz et al., 1999b,c ; Schneider et al., 2007) ont un effet direct non équivoque sur le risque de réforme de la vache, quelles que soient les études réalisées (tableau 2.I). Un comptage en cellules somatiques (CCS) élevé est également un facteur de risque (Caraviello et al., 2005 ; De Vliegher et al., 2005 ; Sewalem et al., 2006) mais l'effet à long terme d'un CCS élevé en début de lactation est négligeable et d'autres facteurs doivent entrer en jeu, notamment la production de lait à long terme (Archer et al., 2013 ; De Vliegher et al., 2005). De même, plus la vache éprouve des épisodes de mammites, plus elle sera à risque de réforme (Bar et al., 2008). On peut également remarquer que la conformation du pis intervient dans la décision de réformer (Caraviello et al., 2003). Pour être complet, on peut ajouter l'association entre les indicateurs métaboliques de la période de transition (acides gras non estérifiés—AGNE, acide β-hydroxybutyrique—ABHB, calcium) et le risque de réforme (Roberts et al., 2012 ; Seifi et al., 2011).

Tableau 2.I – Associations entre maladies et réforme.

Trouble de la santé	Risque de réforme[1]	Auteurs	Origine
Dystocie	1,7‡	Barkema et al., 1992	Pays-Bas
	1,2–1,7‡	Beaudeau et al., 1995	France
	1,1†	Bonneville-Hébert et al., 2011	Québec
	1,5–1,7†	Oltenacu et al., 1990	Suède
	1,2–1,9‡	Rajala-Schultz et al., 1999a,b	Finlande
Avortement	6,2†	Beaudeau et al., 1994	France
	2,4‡	Beaudeau et al., 1995	France
	+	Bell et al., 2010	Écosse
Mammite	5,6–27,8†	Bar et al., 2008	New York
	1,5–4,0†	Beaudeau et al., 1994	France
	1,3–9,4‡	Beaudeau et al., 1995	France
	+	Bell et al., 2010	Écosse
	2,0–10,4‡	Cha et al., 2013	New York
	1,9–3,0‡	Gröhn et al., 1998	New York
	2,4‡	Gröhn et al., 2005	New York
	1,2–2,4‡	Neerhof et al., 2000	Danemark
	1,5–1,8†	Oltenacu et al., 1990	Sweden
	1,4–2,6‡	Rajala-Schultz et al., 1999a,b,c	Finlande
	+‡	Schneider et al., 2007	Suède
Blessures de trayon	6,0†	Beaudeau et al., 1994	France
	1,7–5,7‡	Beaudeau et al., 1995	France
	1,4–3,1‡	Rajala-Schultz et al., 1999a,b,c	Finlande
CCS[2] élevé	1,2–1,7‡	Beaudeau et al., 1995	France
	2,2–4,0‡	Caraviello et al., 2005	États-Unis
	1,1–1,3‡	De Vliegher et al., 2005	Belgique
	1,1–7,9‡	Sewalem et al., 2006	Canada

[1] Rapports de risque‡ ou rapports de cotes†. Valeurs minimales et maximales des différents modèles rapportés dans une étude ; + : risque accru ; − : risque diminué. [2] CCS : comptage en cellules somatiques.

[3] n.s. : non significatif.

Suite page suivante.

Trouble de la santé	Risque de réforme[1]	Auteurs	Origine
Déplacement de caillette	1,3‡	Geishauser et al., 1998	Ontario
	2,4‡	Gröhn et al., 1998	New York
	1,6–6,8‡	Rajala-Schultz et al., 1999a	Finlande
Fièvre de lait	1,6†	Beaudeau et al., 1994	France
	−	Bigras-Poulin, 1985	Ontario
	n.s.[3,†]	Erb et al., 1985	New York
	2,3‡	Gröhn et al., 1998	New York
	4,0†	Hayes et al., 2012	Royaume-Uni
	2,5‡	Rajala-Schultz et al., 1999a	Finlande
	0,7‡	Rajala-Schultz et al., 1999b	Finlande
Rétention placentaire	1,2†	Beaudeau et al., 1994	France
	0,7‡	Beaudeau et al., 1995	France
	+	Bigras-Poulin, 1985	Ontario
	n.s.	Dohoo et al., 1984	Ontario
	n.s.†	Dubuc et al., 2010	Ontario, New York
	n.s.†	Erb et al., 1985	New York
	n.s.‡	Gröhn et al., 1998	New York
	+†	Hayes et al., 2012	Royaume-Uni
	1,4†	Oltenacu et al., 1990	Sweden
	n.s.‡	Rajala-Schultz et al., 1999a	Finlande
Problèmes locomoteurs	n.s.	Barkema et al., 1994	Pays-Bas
	n.s.†	Beaudeau et al., 1994	France
	n.s.‡	Beaudeau et al., 1995	France
	n.s. ou 2,0‡	Booth et al., 2004	New York
	n.s. ou 1,7‡	Cramer et al., 2009	Ontario
	+	Dohoo et al., 1984	Ontario
	n.s.†	Hultgren et al., 2004	Suède
	14,6†	Millan-Suazo et al., 1989	New York
	1,2–6,3‡	Rajala-Schultz et al., 1999a,b	Finlande
	4,2‡	Sogstad et al., 2007	Norvège

[1] Rapports de risque ou rapports de cotes. Valeurs minimales et maximales des différents modèles rapportés dans une étude ; + : risque accru ; − : risque diminué. [2] CCS : comptage en cellules somatiques.

[3] n.s. : non significatif.

Par contre, l'association entre le risque de réforme et d'autres maladies est moins explicite, d'importantes variations étant rapportées selon les études. Si les maladies augmentent généralement le risque de réforme, la force de cette association n'est donc pas toujours spécifique, notamment pour les maladies métaboliques et du système reproducteur. Ainsi le déplacement de caillette est un facteur de risque en début de lactation et surtout immédiatement après son apparition (Geishauser et al., 1998 ; Gröhn et al., 1998 ; Rajala-Schultz et al., 1999a). Ce risque de réforme est influencé par la perte en lait encourue lors du déplacement de caillette (Geishauser et al., 1998). La fièvre de lait est associée avec une réforme précoce des animaux dans certaines études (Beaudeau et al., 1994 ; Gröhn et al., 1998 ; Hayes et al., 2012 ; Rajala-Schultz et al., 1999a,b) alors que d'autres relèvent une absence d'association (Erb et al., 1985) ou même une association négative (Bigras-Poulin, 1985 ; Rajala-Schultz et al., 1999b). La plupart des études ne rapportent pas d'association entre les boiteries et la réforme (Barkema et al., 1994 ; Beaudeau et al., 1994, 1995 ; Booth et al., 2004 ; Dohoo et al., 1984 ; Hultgren et al., 2004 ; Millan-Suazo et al., 1989). Il faut souligner la difficulté à comparer les rapports des risques rapportés dans les différentes études, la définition tant des maladies que de la réforme pouvant varier d'une à l'autre.

Plusieurs facteurs permettent d'expliquer ces différences. L'inclusion des performances de reproduction et/ou de la production laitière dans les différents modèles soit supprime l'association entre maladie et réforme ou y inclut un effet indirect (figure 2.1 ; Beaudeau et al., 1994 ; Geishauser et al., 1998 ; Gröhn et al., 1998 ; Rajala-Schultz et al., 1999b,c). En effet, les maladies ont généralement comme conséquence de provoquer une chute de la production de lait ou une diminution des performances de reproduction (ou les deux ; Fourichon et al., 1999, 2000). Or une vache bonne productrice est moins à risque d'être réformée (Beaudeau et al., 1994, 1995 ; Beaudeau et al., 2000 ; Ducrocq, 1994 ; Gröhn et al., 1998 ; Pinedo et al., 2010a ; Weigel et al., 2003). Lorsqu'inclus dans les modèles, les effets de la production laitière et des performances de reproduction ont, dans toutes les études, un impact plus important sur le risque de réforme que les différents évènements de santé (Beaudeau et al., 2000, et références citées). Cet effet de la production laitière sur le risque de réforme varie cependant avec plusieurs facteurs. On remarque que le niveau de production n'a pas d'effet en début de lactation et que les vaches fortes productrices sont le moins à risque d'être réformées en fin de lactation (Rajala-Schultz et al., 1999b). Rajala-Schultz et al. (1999b) ont aussi démontré que les effets de la parité et d'un statut gestant tardif sur le risque de réforme augmentent après avoir ajusté pour la production de lait.

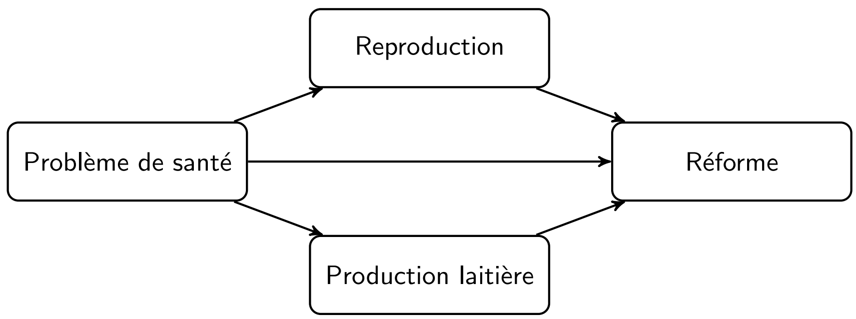

Figure 2.1 – Effets directs et indirects des problèmes de santé sur la réforme.
D. H. Étudiant, 2016.

Ces disparités de résultats posent en réalité la question des liens de causalité entre les différentes maladies du post-partum. L'exemple est donné par la rétention placentaire et la métrite. La rétention placentaire n'est généralement pas considérée comme un facteur de risque pour la réforme (Beaudeau et al., 1995 ; Dohoo et al., 1984 ; Dubuc et al., 2011 ; Erb et al., 1985 ; Gröhn et al., 1998) même si certaines études le rapporte comme tel (Beaudeau et al., 1994 ; Bigras-Poulin, 1985 ; Hayes et al., 2012 ; Oltenacu et al., 1990). Elle est cependant un facteur de risque pour la métrite et l'endométrite (LeBlanc, 2008), ce qui résulte en de mauvaises performances de reproduction (Dubuc et al., 2010 ; Fourichon et al., 2000 ; Gröhn et al., 2000). L'inclusion de variables de confusion varie selon les études et les modèles, reflétant en fait la difficulté à définir les relations entre les différents évènements de santé ayant lieu lors du post-partum et leurs mécanismes de cause et effet (Bonnett et al., 1995 ; Correa et al., 1993 ; Curtis et al., 1985 ; Oltenacu et al., 1990).

À cela s'ajoute le moment d'apparition de l'évènement de santé qui influence aussi le risque de réforme (Beaudeau et al., 1994, 1995 ; Gröhn et al., 1998 ; Rajala-Schultz et al., 1999a). Les raisons de réforme rapportées varient d'ailleurs selon le stade de la lactation (Pinedo et al., 2010b). Le pic de lactation et la période d'insémination sont deux moments-clés pour la prise de décision (Milian-Suazo et al., 1988 ; Seegers et al., 1998). Ainsi, concernant le risque de réforme résultant de la présence de mammite, on remarque que le risque se manifeste à tous les stades de la lactation (Rajala-Schultz et al., 1999a) mais qu'il est surtout présent au début de celle-ci (Beaudeau et al., 1994 ; Gröhn et al., 1998) et durant le tarissement (Beaudeau et al., 1995). Les problèmes de santé ayant un effet important sur la production laitière, perturbant la traite et/ou ayant un pronostic vital réservé (blessures aux trayons, mammites avant le pic de lactation, dystocies, syndrome de la vache à terre, acétonémie, déplacement de caillette) verront la décision de réforme prise rapidement (Beaudeau et al., 1994 ; Geishauser et al., 1998 ; Gröhn et al., 1998), alors que pour ceux affectant moins la capacité de production de l'animal (mammite après le pic, problèmes reproducteurs et métaboliques), les vaches recevront un traitement avant d'être éventuellement réformées. Les décès, blessures et maladies sont plus souvent rapportés comme cause de réforme en début de lactation, alors qu'une faible production et les problèmes de reproduction sont plus souvent consignés comme cause de réforme en fin de lactation.

La difficulté de l'évaluation de l'impact des différents facteurs de risque sur la réforme réside ainsi dans le contrôle adéquat des variables de confusion, la détermination de l'effet direct ou indirect des différents facteurs sur la réforme et la prise en compte du moment d'apparition des différents évènements (figure 2.1 ; Beaudeau et al., 2000). C'est en fait un des problèmes récurrents des études portant sur les maladies du postpartum, où les relations complexes existants entre les différents évènements ayant lieu à ce moment représentent toujours un défi (Correa et al., 1993 ; Curtis et al., 1985 ; Erb et al., 1985 ; Etherington et al., 1985 ; Heringstad et al., 2009 ; Heuer et al., 1999).

Ainsi Gröhn et al. (1997) ont évalué différentes stratégies pour tenir compte de l'effet de la production laitière, et ce dans le cadre de l'effet de la mammite sur la réforme. Ne pas l'inclure était incorrect car on ne tenait pas compte que les plus hautes productrices étaient plus susceptibles à la mammite (Barnouin et al., 2005 ; O'Reilly et al., 2006 ; Schukken et al., 1991). Les autres stratégies développées visaient à tenir compte de la production laitière comme facteur de risque pour la mammite tout en évitant le surajustement pour cette variable (figure 2.1). Elles consistaient à inclure la production de la lactation précédente, évitant ainsi le sur-ajustement mais excluant les primipares. On peut aussi inclure une variable décrivant la production laitière en cours, comme la production cumulative sur 305 jours. Cette variable a le désavantage de comporter en son sein l'effet de la maladie. Son inclusion dans le modèle a réduit l'effet dû à la mammite, mais il restait cependant important, démontrant un effet direct sur la réforme (Gröhn et al., 1998 ; Rajala-Schultz et al., 1999c). Dans le cas où l'on voudrait inclure la production laitière courante, les stratégies vont dépendre de l'objectif de l'étude. Si celui-ci est d'évaluer les effets des maladies sur la réforme en contrôlant pour l'effet confondant de la production laitière, Gröhn et al. recommandait d'utiliser une mesure exprimant le potentiel phénotypique de l'animal plutôt que sa production cumulative, comme : *a*) le meilleur de deux tests du contrôle laitier, dérivé de la formule de Wilmink (Wilmink, 1987), *b*) la production cumulative des 60ers jours (Gröhn et al., 1997), *c*) la classe maximale de production laitière atteinte par une vache à l'intérieur d'un troupeau (Beaudeau et al., 1995 ; Schneider et al., 2007). Si le but de l'étude est de partager les effets directs et indirects d'une maladie, la production courante sous la forme des tests journaliers peut être utilisée (Gröhn et al., 1998 ; Rajala-Schultz et al., 1999c). On peut remarquer que la production laitière est une variable dépendant du temps et donc qu'elle est à la fois un facteur de confusion et une variable intermédiaire, conduisant à des risques biaisés si des précautions particulières ne sont prises (Robins et al., 2000). Mais ce biais particulier n'a été identifié et sa correction n'a été développée que dans les années suivant les stratégies proposées par Gröhn et al. (1997), qui n'a dès lors pu les considérer.

Différentes stratégies existent aussi pour tenir compte de la reproduction. Erb et al. (1985) ont utilisé la méthode des pistes causales pour différencier les effets directs et indirects de la rétention placentaire, de la métrite et des ovaires kystiques.

Une autre stratégie utilisée par Gröhn et al. (1998) est d'inclure le statut de gestation comme variable dépendant du temps (et ceci dans un modèle des risques proportionnels de Cox). Cette stratégie ne tient cependant pas compte de la gestion de la reproduction par le producteur, où il peut décider de ne pas mettre sa vache à la reproduction, qu'elle soit malade ou non. Elle ne tient pas compte non plus que l'animal n'est pas à risque pour la période anovulatoire du post-partum. Un moyen d'en tenir compte serait d'inclure une variable représentant le nombre d'inséminations de la vache (Beaudeau et al., 1995 ; Gröhn et al., 1998 ; Rajala-Schultz et al., 1999b).

Une manière classique d'explorer la relation entre les maladies et la réforme a été par l'utilisation de techniques de régression (régression logistique) et d'expression de risque de réforme. Lorsque la maladie est évaluée comme étant indépendante du temps, son effet sur la réforme est supposée être le même avant et après sa survenue, ce qui est possible si la maladie survient tôt dans la lactation. Par contre, si elle est considérée comme dépendante du temps, son effet sera différent avant et après son apparition (Beaudeau et al., 2000). Dès lors, l'analyse de survie (Cox, 1972) est souvent la plus appropriée et est généralement utilisée (Beaudeau et al., 1995 ; Ducrocq et al., 1988 ; Gröhn et al., 1997).

Les raisons spécifiques de réforme rapportées par les producteurs varient d'une exploitation à l'autre (Beaudeau et al., 2000 ; Millan-Suazo et al., 1989 ; Pinedo et al., 2010a). Les raisons majoritairement rapportées sont d'abord les problèmes de reproduction (30% des cas et plus ; Chiumia et al., 2013 ; Esslemont et al., 1997 ; Seegers et al., 1998 ; Stevenson et al., 1998) suivis par la production laitière et la mammite (Bascom et al., 1998 ; Chiumia et al., 2013 ; Pinedo et al., 2010a). La moitié des raisons de réforme a pour origine la santé de l'animal (Beaudeau et al., 2000 ; Dohoo et al., 1984 ; Esslemont et al., 1997 ; Fetrow et al., 2006 ; Seegers et al., 1998 ; Sol et al., 1984 ; Stevenson et al., 1998). Les raisons rapportées ont toutefois été démontrées comme ayant une forte composante subjective (Bergeå et al., 2016) et le lien entre raison rapportée et troubles de santé enregistrés est ténu (Beaudeau et al., 2000). Il reste cependant que les conditions de santé sont substantielles dans la décision de réformer un animal ou de ne pas le faire saillir.

2.2.2 Longévité des vaches et profitabilité du troupeau

L'élevage des génisses de remplacement peut compter jusqu'à 20% des dépenses totales d'un troupeau, poste le plus conséquent après les coûts d'alimentation et de main-d'oeuvre (Gabler et al., 2000 ; Heinrichs, 1993 ; MAPAQ, 2014). La décision de réformer un animal est donc cruciale pour la profitabilité des opérations de la ferme laitière (Dijkhuizen et al., 1987). Augmenter la longévité d'animaux en santé permettrait de maximiser les revenus des producteurs laitiers tout en diminuant les coûts nécessaires au maintien de la taille du troupeau. D'un point de vue financier, une vache étant un bien qui peut être amorti, plus elle restera longtemps dans le troupeau plus le coût de son remplacement pourra être étalé dans le temps. Il est donc concevable de vouloir diminuer ces coûts d'élevage en optimisant l'utilisation des multipares, étant convenu qu'une vache à maturité maximise la production laitière et le retour sur investissement du producteur (Madouasse, 2009). Pourtant, on remarque que les troupeaux produisant le plus ont aussi généralement les taux de réforme les plus élevés (figure 2.2 ; De Vries, 2013). Ceci a aussi été observé par Dechow et al. (2008) pour les taux de réforme lors des soixante premiers jours en lait. Ce paradoxe est aussi retrouvé pour plusieurs indicateurs de performance des troupeaux (figure 2.2), où le risque de réforme est accru dans les troupeaux avec un CCS moyen faible (Caraviello et al., 2005) alors que la relation avec les indicateurs de reproduction peut être plus mitigée.

La décision de réforme prend en compte le contexte global de l'exploitation laitière (Lehenbauer et al., 1998). Pour une vache donnée, le risque de réforme consécutif à un trouble de santé ou à sa production dépend fortement des caractéristiques de l'élevage (disponibilité de génisses de remplacement, quota, etc. ; Beaudeau et al., 2000). L'effet troupeau a été identifié comme devant être significatif dans le risque de réforme (Beaudeau et al., 1995 ; Emanuelson et al., 1998 ; Gröhn et al., 1998 ; Lehenbauer et al., 1998). Par exemple, le risque de réforme est plus important pour les vaches faisant partie d'un troupeau où la 1re insémination intervient plus tôt et

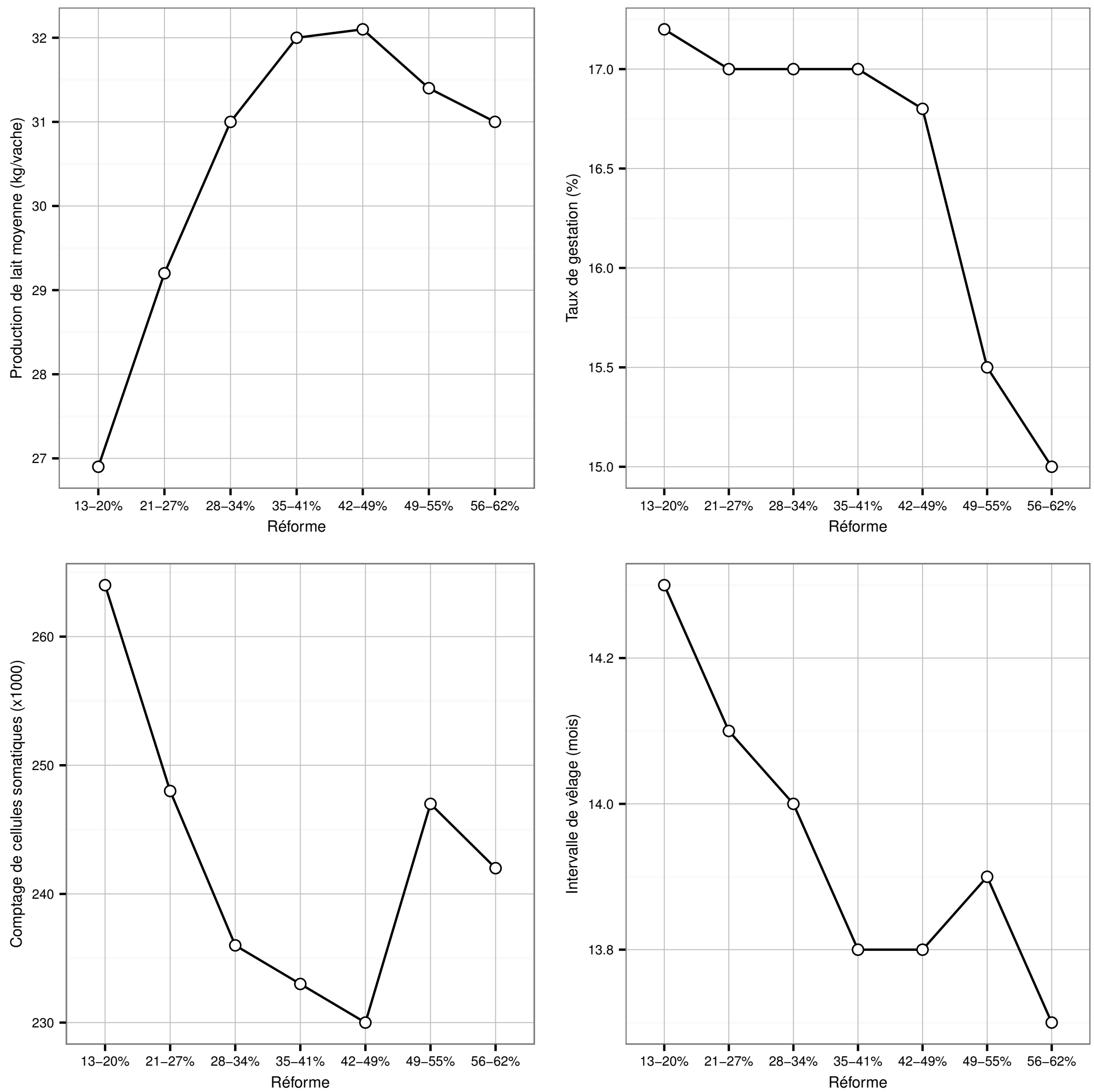

Figure 2.2 – Indicateurs de performances de troupeau et taux de réforme
(source : DRMS [a], 13 357 troupeaux, est des États-Unis ; compilation par A. De Vries (2013). « Cow longevity economics : The cost benefit of keeping the cow in the herd ». *Cow Longevity Conference*. Sweden : DeLaval, p. 22–52).
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a. http://www.drms.org/

dans les troupeaux ayant un programme de synchronisation des chaleurs, même si le rapport des risques est faible (HR $\leq$ 1,10 et 1,08 respectivement ; De Vries et al., 2010). Encore une fois, l'effet du troupeau peut varier d'une étude à l'autre et, par exemple, on retrouvera (Pinedo et al., 2010a) ou non (Smith et al., 2000) un risque individuel de réforme réduit dans les troupeaux à forte production. L'association est donc fragile entre le taux de réforme d'un troupeau et des facteurs de troupeau tels que le niveau de production, la qualité du lait et la reproduction (De Vries, 2013). Comme nous l'avons vu à la section 2.2.1, la production laitière de la vache, sa gestation, son âge et sa bonne santé vont lui permettre d'éviter ou de retarder sa réforme. Mais ces éléments ne sont pas reliés directement à leur équivalent au niveau du troupeau, différentes combinaisons de santé de troupeau et de taux de réforme sont possibles.

D'autre part, les revenus potentiels d'une taure peuvent éclipser les bénéfices obtenus en conservant une vache plus vieille. Il ne faut en effet pas oublier les coûts en plus des revenus additionnels de garder des animaux plus longtemps. À partir de données québécoises, on peut remarquer que les profits par vache sont plus importants dans des troupeaux à faible taux de réforme (à peu près 40 cents supplémentaires par jour et par vache à l'intérieur d'une même strate de production, figure 2.3 ; Blais et al., 2007). Ce gain équivaut en fait à passer d'une strate de production à la strate supérieure en conservant le même taux de réforme. À réforme égale, le gain peut s'élever à 1,75 dollar par vache et par jour entre la strate des troupeaux les moins productifs et celle des plus productifs.

La diminution de l'incidence des maladies peut accroître la production de lait des vaches et leur fertilité, représentant un effet bénéfique sur les coûts de remplacement et sur la profitabilité de la vache. Mais cette réduction des coûts de remplacement n'est qu'un aspect de l'accroissement de la longévité. D'autres variables doivent être considérées, comme la production totale du troupeau, les coûts d'alimentation, la valeur des veaux produits, etc.

Longévité et profitabilité ne vont donc pas nécessairement de paire, la décision de réforme devant prendre en compte les éléments tant individuels que de troupeau,

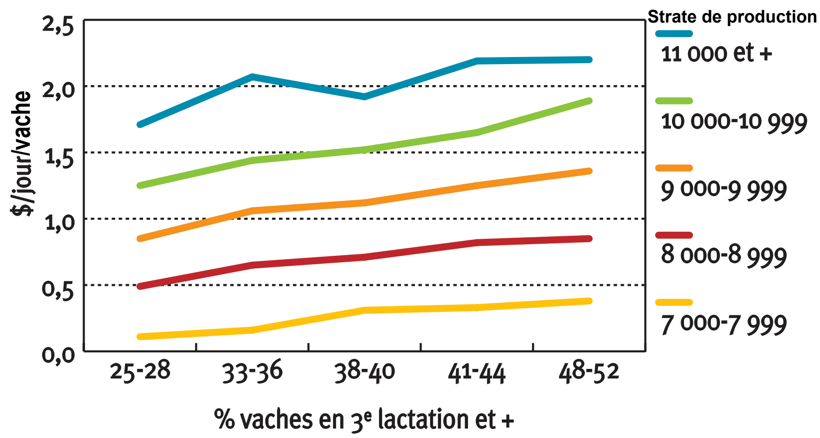

Figure 2.3 – Évolution du profit par jour de vie par vache en fonction de la longévité selon différentes strates de production de troupeau (kg), Québec.
C. Blais et al. (2007). « Améliorer la longévité des vaches, est-ce vraiment payant ? » : *Le producteur de lait québécois*, p. 17–18. URL : `https://www.agrireseau.net/bovinslaitiers/documents/valacta_lplq_2007-12_longevite.pdf`.

ainsi que la gestion de la ferme (Dohoo et al., 1993).

2.3 Les décisions de la réforme

La valeur accordée à un animal est déterminée par le fruit que le producteur peut retirer de celui-ci en tant que ressource (McInerney, 1987). Dans cette perspective, une affection touchant un animal n'est pertinente que si elle perturbe la transformation de cette ressource et donc le bénéfice que le producteur pourrait en retirer, par exemple par une diminution de sa production, voire par une disparition de cette ressource en cas de mortalité. Par conséquent un évènement qui ne perturbe pas la ressource n'est pas considéré comme un problème (McInerney, 1988, 1996). En réaction à une perturbation de la ressource causée, par exemple, par une maladie, il est nécessaire d'établir des stratégies visant à réduire leur effet négatif (McInerney, 1987, 1988 ; McInerney et al., 1992). Une intervention vétérinaire est un type d'intervention ayant un horizon de temps rapproché. Une autre réaction peut également être de ne pas traiter l'animal et de le remplacer par un autre qui sera plus profitable, si pas immédiatement à tout le moins dans le futur (Van Arendonk, 1988).

Le producteur est donc amené à prendre régulièrement des décisions pour gérer les conséquences socio-économiques des perturbations touchant ses animaux, comme par exemple les effets sanitaires des maladies dans son troupeau (Dijkhuizen et al., 1995, 1997). Ainsi, la stratégie qui vise à minimiser les pertes totales, c'est-à-dire la somme des pertes de production et des dépenses de contrôle, est généralement considérée comme la plus profitable (McInerney et al., 1992). Mais le producteur est libre de faire certains choix particuliers, comme par exemple d'opérer une sélection génétique, ou devoir répondre à certaines contraintes comme des réglementations particulières, des quotas, l'impossibilité d'étendre ses terres ou d'agrandir ses bâtiments, etc. (Wallace et al., 2002) Un cadre simple d'analyse peut alors être défini comme comportant une partie biologique et une partie économique (figure 2.4 ; McInerney, 2001). La composante biologique a été illustrée dans la section 2.2.1 avec les facteurs de risque des maladies. La décision de réforme est toutefois une décision économique. Le producteur espère un meilleur profit en remplaçant un certain animal plutôt qu'en le gardant (Van Arendonk, 1988). Pour ce faire, le producteur devra répondre à trois questions : quand réformer ? qui réformer ? et combien de sujets de remplacement élever ?

2.3.1 Quand réformer ?

La décision peut être évidente et entraîner un retrait rapide de l'animal. Ce cas de figure a lieu lorsque la vache représente un risque pour la santé des autres animaux présents dans le troupeau, par exemple par la transmission de maladies infectieuses, lorsqu'elle risque de faire augmenter le taux de cellules somatiques du troupeau, entraînant par là même des pénalités pour le producteur, quand son bien-être est en jeu, quand elle ne produit déjà presque plus de lait ou si elle souffre d'un problème de santé vital. La situation du troupeau peut moduler l'échéance, par exemple l'accélérant si le troupeau est hors quota ou en le retardant s'il est en sous-production. Mais souvent la situation est moins claire et le moment optimal de réforme n'est pas évident à déterminer. Le style de gestion et les objectifs de

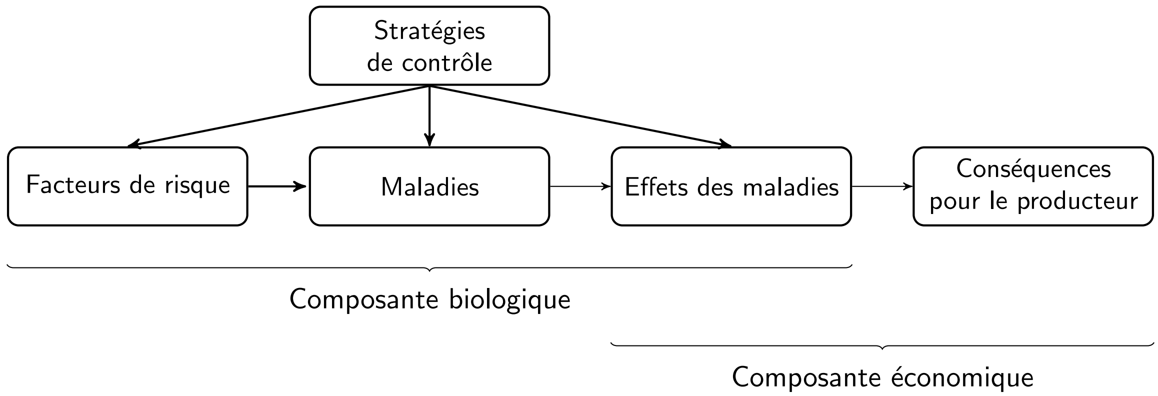

Figure 2.4 – Composantes d'un modèle en économie de la santé animale. J. P. McInerney (2001). « Conceptual considerations when developing decision support tools for herd health management ». *CEPROS Workshop*. Sous la dir. de H. Houe et al. Foulum, Denmark : Research Centre for the Management of Animal Production and Health, Danish Institute of Agricultural Sciences, p. 95–102.
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production, ainsi que les stratégies de réforme peuvent varier d'un producteur à l'autre (Beaudeau et al., 1996). Ceci peut conduire à une variété de décision en fonction du troupeau, pour une même vache dans une situation identique (Beaudeau, 1995). La décision consiste alors à déterminer au mieux qui devrait être réformé (De Vries, 2006b).

2.3.2 Qui réformer ?

On peut convenir dans un premier temps que les meilleurs éléments du troupeau doivent être conservés alors que les pires seront candidats à la sortie du troupeau. Entre ces deux extrêmes certains animaux seront plus ou moins probables d'être réformés, et un classement peut être établi entre eux. Pour ce faire, et admettant une taille de troupeau stable, il convient de mettre en balance le bénéfice marginal futur, sur une certaine période, de la vache présente dans le troupeau et le bénéfice moyen qui serait obtenu avec la jeune taure de remplacement pendant cette même période (Renkema et al., 1979). Une vache devrait donc être conservée dans le troupeau aussi longtemps que le bénéfice marginal qu'elle rapporte est plus important que celui qui serait généré par une jeune taure de remplacement ou un autre animal qui prendrait sa place (Renkema et al., 1979). La décision de réformer une vache ne vient donc pas du fait qu'elle ne rapporte plus au producteur, mais bien qu'une autre sera plus profitable (Dijkhuizen et al., 1985).

Cette évaluation demande cependant un assemblage important d'informations pour amener à une amélioration de la compréhension de la production et conséquemment de prendre les meilleures décisions. Plusieurs modèles informatiques ont été développés pour optimiser la décision de réforme en définissant un indice qui permet de classer les vaches selon leur rentabilité future, appelé *Cow Value* ou « prime à la rétention » (*Retention Pay-Off*—RPO ; Cabrera, 2012 ; Cha et al., 2011 ; De Vries, 2004 ; Kristensen, 1989 ; Nielsen et al., 2010 ; Van Arendonk et al., 1985).

Quel que soit le modèle utilisé, la gestation est un facteur déterminant dans la détermination de cet indice (Cabrera, 2012 ; De Vries, 2006a ; Kalantari et al., 2010 ; Nielsen et al., 2010). Celui-ci décroît lorsque la vache n'arrive pas à être gestante, circonstance aggravée par l'évolution de la courbe de lactation lors de la période d'inséminations. La production de la vache intervient également et les vaches les moins productives atteignent un RPO négatif six mois plus tôt que les vaches les plus productives (De Vries, 2006b). Le RPO est également plus faible pour les vaches âgées et les vaches qui sont devenues gestantes tardivement dans leur lactation (Kalantari et al., 2012). Dans un système soumis à la gestion de l'offre par contingentement de la production, on remarque cependant que les vaches non gestantes en milieu ou fin de lactation et les moins bonnes productrices bénéficient d'une rétention plus longue que dans un système sans cette gestion de l'offre (Kristensen, 1989). De plus, les différences de production et de stades de lactation entre vaches ont un effet plus limité, résultant en une moins grande variation du RPO entre les vaches d'un même troupeau. Le classement des vaches est donc modifié lorsqu'un système de quota de production est présent, car la fonction de maximisation n'est plus basée sur la valeur actualisée de la vache mais sur le revenu net moyen à long terme d'un kg de lait produit. Dans ce cas, on peut escompter que le risque de réforme résultant d'une production plus faible soit réduit.

Ces modèles partent du postulat que le profit par vache et par période de temps est maximisé dans un troupeau ayant un inventaire fixe et une provision illimitée d'animaux de remplacement (De Vries, 2013). Souvent, le taux de réforme optimal n'est pas leur objectif.

Du fait de leur complexité, peu de ces modèles mathématiques ont trouvé une application pratique dans le processus décisionnel quotidien des producteurs laitiers (Groenendaal et al., 2004). L'adoption limitée de ces modèles par les utilisateurs peut provenir tant de la difficulté à comprendre ce qu'ils font avec les données fournies (« boîte noire ») que d'une valeur ajoutée qui serait perçue comme modérée. On peut concevoir qu'ils ne répondent pas pleinement aux demandes des utilisateurs, étant des systèmes linéaires, faisant peu de place aux interactions et à l'intégration des aspects dynamiques du système de production (Sauvant, 1999). On considère dès lors communément que la décision de réforme se contentera de prendre en compte les éléments suivants (Lehenbauer et al., 1998) :

- la production de la vache ;
- son stade de lactation, son statut reproducteur et son âge ;
- sa valeur génétique ou sa contribution à la valeur du troupeau, sa contribution à la production totale du troupeau, ou à tout le moins une estimation de son potentiel de production ;
- ses attributs individuels, comme ses problèmes de santé, sa conformation ;
- la dynamique du troupeau, sur le court et le long terme (par exemple la gestion du quota de lait, la disponibilité de places et de taures de remplacement, etc.).

Malgré l'importance du processus décisionnel de réformer un animal, ce choix reste donc souvent informel et itératif. Si on peut croire que le choix effectué est généralement rationnel, on peut douter qu'il soit optimal dans tous les cas.

2.3.3 Combien élever ?

Au Québec, les animaux de remplacement sont généralement élevés à la ferme pour entrer ensuite dans le troupeau des animaux en lactation. Élever trop de ces animaux de remplacement représente cependant un fardeau financier pour l'exploitation laitière. Mais ne pas remplacer certains animaux peut mener à en garder qui ne sont plus assez productifs ou qui posent un risque pour le reste du cheptel s'ils sont porteurs de maladies contagieuses. La stratégie de réforme a donc des implications sur le capital à investir, l'élevage des animaux de remplacement, le contrôle des maladies, la gestion de la reproduction (incluant la sélection génétique) et l'achat d'animaux.

Les profits futurs en ne réformant pas une vache doivent tenir compte des coûts d'opportunité consentis en renonçant à la taure de remplacement (Van Arendonk, 1991). Garder un animal plus longtemps dans le troupeau ne représente un coût d'opportunité nul que si de la place est disponible pour accueillir une taure sans faire sortir une autre vache. Donc, dans un troupeau en expansion, tant que la remplaçante n'a pas un potentiel de revenu plus important que la vache en place, cette vache peut ne pas être remplacée et l'expansion du troupeau résulte en une proportion plus importante de primipares. On a un cas semblable quand un besoin à court terme doit être rempli, comme un quota par exemple, où des vaches seront gardées plus longtemps que requis par leurs performances, tant de production que de santé. Si la taille du troupeau est stable (une vache sort pour une qui entre), le gestionnaire devrait donc tenter de maximiser la valeur actualisée nette totale par vache sur une planification à long terme raisonnable du troupeau, c'est-à-dire avoir les vaches les plus profitables pour chaque place disponible (son produit marginal est plus important que le profit escompté d'une génisse de remplacement ; Eicker et al., 2003 ; Lehenbauer et al., 1998). En effet, chaque exploitation laitière a un inventaire optimal de vaches afin de faire l'usage le plus rentable que possible de l'espace disponible dans l'étable, et ce dans les limites imposées par le quota de lait (Eicker et al., 2000). La décision de réforme doit tenir compte de cet aspect logistique afin de permettre l'occupation d'un maximum de places disponibles par des animaux qui sont les plus profitables (Eicker et al., 2003).

2.4 Les contextes de la réforme

Le processus de la réforme peut être vu comme un tissu complexe de relations et de rétroactions entre le troupeau, la ferme, la vache et la personne qui décide de réformer. Ces décisions sont dérivées de considérations économiques (prix du lait, prix de la vache de réforme, coûts de remplacement, etc.), de la capacité de la ferme, du statut de production et de santé de la vache, de l'incidence des maladies et de la mortalité du troupeau, des taures de remplacement disponibles, de la biosécurité, etc. (Beaudeau et al., 1995 ; McCullough et al., 1996) De plus, le jugement du producteur, donc une certaine subjectivité, a un effet sur le choix de l'animal à réformer (Beaudeau et al., 1995 ; Bigras-Poulin et al., 1985).

Les facteurs individuels, de la vache, sont très importants dans la réforme de celle-ci, surtout si l'on considère la gestion à court terme du troupeau et de la ferme. Mais les facteurs de troupeau et les contraintes reliées à l'exploitation laitière peuvent ajuster à la fois les décisions individuelles et les stratégies de réforme du troupeau (De Vries, 2013).

Vache et troupeau représentent sans doute deux niveaux hiérarchiques différents pour exprimer la variation du risque de réforme, phénomène déjà observé, par exemple, entre production laitière et reproduction (Bello et al., 2012, 2013 ; LeBlanc, 2010a). Selon les résultats des simulations, la recherche d'une amélioration de la longévité ne s'applique pas de la même manière pour toutes les vaches, se concentrant essentiellement sur les meilleures productrices qui sont à favoriser (Cabrera, 2012 ; Demeter et al., 2011 ; Heikkilä et al., 2008). La longévité globale des animaux du troupeau dépend fortement des contraintes économiques de la ferme, extérieures à la vache. La longévité d'une certaine vache se fera souvent aux dépens du départ plus rapide d'une autre afin d'optimiser la profitabilité du troupeau. L'amélioration de la longévité est donc dépendante du système de production, incluant notamment la gestion du quota et la dynamique du troupeau (Groen et al., 1997 ; Harris et al., 1993 ; Kristensen, 1989). La production laitière, les coûts d'opération autres que l'alimentation et le taux de gestation sont eux plus importants que le taux de réforme pour l'amélioration de la profitabilité de l'entreprise (Dhuyvetter et al., 2007).

La longévité d'une vache dépend donc de caractéristiques qui lui sont propres mais également d'autres qui ne sont reliées ni à sa santé ni à ses performances. Le contexte dans lequel elle évolue est important pour nuancer son risque de réforme. Ce contexte comprend le troupeau auquel elle fait partie mais également la manière dont est opéré l'entreprise laitière. Ceci inclut également la gestion des animaux de remplacement et la pression qu'ils exercent sur chaque tête du troupeau (Mohd Nor et al., 2015). En outre, la décision de réforme peut être modulée par les objectifs, préférences et jugements du producteur (Bergevoet et al., 2004 ; Bigras-Poulin et al., 1985 ; Edwards-Jones, 2006), celui-ci étant le lien entre les opérations techniques et économiques de son élevage (Sauvant, 1999).

2.5 Remarques critiques

On peut constater que plusieurs éléments de la littérature sur la réforme sont constitués de communications lors de conférences, souvent destinées aux vétérinaires praticiens ou aux producteurs (Eicker et al., 2003 ; Fetrow, 1987 ; Rapnicki et al., 2003, p.ex.). Le niveau de preuve apporté par ces communications doit être balancé par la qualité de leurs auteurs, reconnus experts dans leur domaine, et la qualité de la conférence (avec comité de pairs ou non). La réforme a un aspect concret qui parle directement aux différents intervenants en ferme, de par son impact sur les ressources de l'exploitation, ses retombées économiques et ses connexions avec les diverses composantes de la régie de l'entreprise laitière. Un certain nombre de connaissances sur la réforme reste malheureusement empirique et la qualité des communications ne remplacent pas des observations rigoureuses. Elles sont cependant souvent les seules disponibles sur une série de sujets concernant la réforme.

Pour comprendre les mécanismes de la réforme, il est important de pouvoir la quantifier. Il n'y a cependant pas d'étude d'incidence de la réforme pour le Québec et les seules évaluations sont soit de Statistique Canada soit du contrôle laitier, avec des définitions et évaluations variables.

Les associations entre les évènements de santé et la réforme ne sont pas toujours clairement établies et/ou la force de l'association peut varier grandement d'une étude à l'autre, voire même au sein de la même étude. Les interrelations entre variables ne sont généralement pas examinées et définies afin de proposer le meilleur modèle causal (Martin, 2008). De plus, si la modélisation du risque de réforme à l'aide de modèle de survie inclut parfois l'utilisation de mesures répétées (Bar et al., 2008 ; Cha et al., 2013 ; Gröhn et al., 1997), ces études ne prennent pas en compte la situation particulière où une variable dépendant du temps peut à la fois être une variable de confusion et intermédiaire (Robins et al., 2000). On peut aussi remarquer que l'essentiel de la littérature sur les facteurs de risque se concentrent sur une lactation parmi d'autres dans la vie de l'animal mais peu s'intéressent à l'intégralité de sa vie. Lorsque c'est le cas, l'objectif de l'étude se situe plutôt dans le cadre de l'estimation de phénotypes et de l'amélioration de la longévité (Ducrocq, 1994 ; Jenko et al., 2013 ; Roxström et al., 2003). Les difficultés d'interprétation de la relation entre différentes variables et le risque de réforme ne se limite pas à la vache, mais aussi au troupeau dans lequel elle vit. Même si un effet troupeau a été constaté sur le risque de réforme (Beaudeau et al., 1995), seulement trois études s'y sont intéressées (Batra et al., 1971 ; Mohd Nor et al., 2014 ; Smith et al., 2000). Aucune cependant n'a envisagé l'utilisation de modèles multiniveaux pour décomposer la variabilité entre les différents niveaux hiérarchiques (Stryhn et al., 2014).

La littérature s'accorde pour reconnaître la complexité de la réforme. Des modèles mathématiques existent afin de faciliter le processus de décision mais ils semblent peu utilisés. La décision reste donc très souvent empirique, retombant sur l'utilisation de quelques critères (Lehenbauer et al., 1998), cependant non démontrés. On convient également qu'une ferme n'est pas l'autre et que les objectifs poursuivis, son environnement technico-économique voire la personnalité du producteur vont résulter en un style de gestion et des résultats variables. Cela est sans doute vrai mais peut-on le généraliser à la décision de réforme ou à la stratégie de réforme mise en place ? Et si cette stratégie et le taux de réforme sont si importants pour la profitabilité de l'entreprise laitière, il n'existe pas d'études comparatives de la rentabilité des fermes laitières en fonction de leur taux de réforme. Seules sont disponibles dans des revues techniques des appréciations en fonction de différentes variables substitutives devant représenter cette rentabilité. La place du taux de réforme dans le processus de décision et dans la profitabilité de la ferme laitière reste encore à être établi.

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CHAPITRE 3

OBJECTIFS

Ce projet vise à décrire la réforme dans les troupeaux laitiers du Québec. Plus spécifiquement, les objectifs sont les suivants :

— Quantifier le taux de réforme au Québec ;

— Déterminer des profils de troupeaux selon leur gestion, leurs performances de production et reproduction, et leurs incidences de maladies. Relier ces profils à un taux de réforme ;

— Déterminer les variables contextuelles d'intérêt à inclure dans des analyses multiniveaux sur le risque de réforme ;

— Explorer les effets des déterminants au niveau vache et au niveau troupeau sur les variations de réforme. Évaluer si, au-delà des facteurs de la vache, le troupeau influence le risque individuel de réforme ;

— Estimer l'effet causal de la mammite clinique sur la réforme par l'utilisation d'un modèle marginal structural ;

— Identifier les critères de décision utilisés lors de la réforme par les producteurs et les différents intervenants à la ferme.

CHAPITRE 4

CULLING FROM THE HERD'S PERSPECTIVE—EXPLORING HERD-LEVEL MANAGEMENT FACTORS AND CULLING RATES IN QUÉBEC DAIRY HERDS

Denis Haine[1], Hector Delgado[2], Roger Cue[2], Asheber Sewalem[3], Kevin Wade[2], René Lacroix[4], Daniel Lefebvre[4], Julie Arsenault[1], Émile Bouchard[1], Jocelyn Dubuc[1]

[1]Faculté de médecine vétérinaire, Université de Montréal, 3200 rue Sicotte, C.P.5000, St-Hyacinthe, Québec, Canada J2S 7C6

[2]Department of Animal Science, McGill University, 21 111 Lakeshore Road, Ste-Anne-de-Bellevue, Québec, Canada H9X 3V9

[3]Guelph Food Research Centre, Agriculture and Agri-Food Canada, 93 Stone Road West, Guelph, Ontario, Canada N1G 5C9

[4]Valacta Inc., 555 boul. des Anciens-Combattants, Ste-Anne-de-Bellevue, Québec, Canada H9X 3R4

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Contributions

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D. Haine	X	X	X		X	X
H. Delgado		X				X
R. Cue	X					X
A. Sewalem	X					X
K. Wade	X					X
R. Lacroix		X				X
D. Lefebvre		X				X
J. Arsenault			X	X	X	X
É. Bouchard	X					X
J. Dubuc	X		X	X	X	X

Abstract

The relationship between cows' health, reproductive performance or disorders and their longevity is well demonstrated in the literature. However these associations at the cow level might not hold true at the herd level, and herd-level variables can modify cow-level outcomes independently of the cows' characteristics. The interaction between cow-level and herd-level variables is a relevant issue for understanding the culling of dairy cows. However it requires the appropriate group-level variables to assess any contextual effect. Based on 10 years of health and production data, the objectives of this paper are: (a) to quantify the culling rates of dairy herds in Québec; (b) to determine the profiles of the herds based on herd-level factors, such as demographics, reproduction, production and health indicators, and whether these profiles can be related to herd culling rates; and (c) to determine potential contextual variables affecting the culling risk of individual cows. A retrospective longitudinal study was conducted on data from dairy herds in Québec, Canada, by extracting health information events from the dairy herd health management software used by most Québec producers and their veterinarians. Data were extracted for all lactations taking place between January 1st, 2001 and December 31st, 2010. A total of 432,733 lactations from 156,409 cows out of 763 herds were available for analysis. Thirty herd-level variables were aggregated for each herd and years of follow-up, and their relationship was investigated by Multiple Factor Analysis (MFA). The overall yearly culling rate was 32%, with a 95% confidence interval (CI) of [31.6,32.5]. The dairy sale rate by 60 days in milk (DIM) was 3.2% [2.8,3.6]. The yearly culling rate within 60 DIM was 8.2% [7.9,8.4]. The explained variance for each axis from the MFA was very low: 14.8 for the first axis and 13.1% for the second. From the MFA results, we conclude there is no relationship between the groups of herd-level indicators, demonstrating the heterogeneity among herds for their demographics, reproduction and production performance, and health status. However, the profiles of herds could be determined according to specific domains independently. The relationships between culling rates and specific herd-level variables were limited to

livestock sales, proportion of first lactation cows, herd size, proportion of calvings occurring in the fall, longer calving intervals and reduced 21-day pregnancy rates, increased days to first service, average age at first calving, and reduced milk fever incidence. The indicators found could be considered as contextual variables in multilevel model-building strategies to investigate cow culling risk.

Keywords culling, dairy cow, herd level, herd characteristics, multiple factor analysis (MFA).

4.1 Introduction

In the dairy cow production cycle, a cow will eventually reach a point where she is no longer an economic asset for the producer, and a decision will have to be made whether to keep or remove her from the herd. Culling is the removal of a cow from the herd, most often replacing her with another one, probably a first-lactation heifer (Hadley et al., 2006). Culling rates greater than 30% are common in American and Canadian dairy herds (Fetrow, 1987; Radke et al., 2000; Smith et al., 2000), despite common recommendations to lower cull rates. These higher cull rates can sometimes be viewed, wrongly or not, as a sign of management failure (Eicker et al., 2003).

A great deal of the literature on the culling of dairy cows looks at the cow-level relationship between longevity and either health (Beaudeau et al., 1994; Beaudeau et al., 2000; Gröhn et al., 1998; Rajala-Schultz et al., 1999a) or reproductive performance and disorders (De Vries et al., 2010; Rajala-Schultz et al., 1999b; Schneider et al., 2007), demonstrating their effects on cow culling risk. However, these cow-level associations may not hold true at the herd level, i.e. herd-level disease rates, production, or reproduction performance, might not illustrate the same relationships with culling events as seen at the cow-level. Indeed, group-level variables can affect or modify individual-level outcomes independently of the characteristics of the individuals (Diez Roux, 1998). Therefore there is an interest in integrating the population context into individual-level analyses to untangle the relationships between the variables on various levels (Guthrie et al., 2001). Multilevel models can achieve this goal by decomposing the variability across hierarchical levels (Stryhn et al., 2014).

Even though a large herd effect on the risk of being culled has been mentioned by a few studies (Beaudeau et al., 1995; Emanuelson et al., 1998; Gröhn et al., 1998), we could find only three studies that assessed the association between herd culling rates and some herd-level management factors (Batra et al., 1971; Mohd Nor et al., 2014; Smith et al., 2000). While all three studies found a positive relationship between the culling rate and average herd production, the results were discordant regarding the association with herd size, from no effect (Batra et al., 1971), to increased cull rates in larger herds (Smith et al., 2000), or in smaller ones (Mohd Nor et al., 2014). Mohd Nor et al. (2014) also found higher cull rates in herds with worse reproduction performance parameters and higher average somatic cell counts (SCC). But several more herd characteristics can potentially modify the cow culling risk, such as the availability of heifers, milk quotas, the farmer's attitude towards risk and uncertainty, the milk and beef market, etc. (Beaudeau et al., 2000) The combination of cow- and herd-level factors is a relevant issue for the understanding of the culling of dairy cows. However, it requires the appropriate group-level variables to assess any contextual effect.

Demographics, reproduction, production, and health factors are, together, determinants in the administration of a farm enterprise. Susser (1994) defined a contextual variable as an aggregate-level variable derived from a compilation of individual attributes having an effect that is beyond the sum of their parts. It can be hypothesized that contextual variables grouped into the four domains above could define certain types of herds and be related to herd culling rates. Many variables can be constructed within these domains, but the domains might not provide the same number of variables, and they can potentially be correlated. Multiple Factor Analysis (MFA; Escofier et al., 1994), which analyses several groups of variables defined for the same set of observations, revealing the relationships between these groups of variables, can be used in such a context. It is a generalization of Principal

Component Analysis (PCA) applied to all variables, within which each group of variables is weighted, thus resulting in a reduced number of uncorrelated variables. Common factors are generated for both variables and groups of variables, allowing the MFA to take into account the heterogeneity of the groups of variables (Abdi et al., 2013). The main variables and groups of variables that differentiate herds can therefore be identified, and their commonalities and discrepancies analysed. The identification and characterization of different contextual profiles would help the understanding of farm management and decision-making in the context of the culling decision, providing information on the required group-level variables to include in multilevel analysis.

Based on 10 years of retrospective dairy cow health and production data, the objectives of this paper are: (a) to quantify the culling rates of Québec dairy herds; (b) to determine the profiles of herds based on herd-level factors such as demographics, reproduction, production and health indicators, and whether these profiles can be related to herd culling rates; and (c) to determine potential contextual variables for use in multilevel modelling of culling risk.

4.2 Materials and methods

4.2.1 Dataset

A retrospective longitudinal study was conducted on data from dairy herds in the Province of Québec, Canada, by extracting health information events from *DSA Laitier* (DSAHR Inc., Saint-Hyacinthe, QC, Canada), the dairy herd health management software used by more than half of producers in Québec and their veterinarians. A purposive sample was created by extracting data for all lactations taking place between January 1st, 2001 and December 31st, 2010 (249,536 cows from 3735 herds), keeping herds that had data for a minimum of three consecutive years with *DSA Laitier* within the study period and for which at least one culling was recorded. Production data were obtained from the only Québec dairy herd improvement (DHI) service provider (Valacta, Sainte-Anne-de-Bellevue, QC, Canada). The health and production data were matched based on herd- and cow-level identification. If not successful, further matching was tried based on birth date, calving dates, and health and production history. Only herds for which at least 95% of the lactations from the health dataset could be matched with data from the production dataset were kept. Herds with less than 30 animal-years for a given year were removed for that year of follow-up. Cows were included for their full interval from calving to subsequent calving, or culling. Cows with calving intervals, or interval between last calving and the end of data, longer than 580 days were censored at their last calving date. If this censoring resulted in their first calving date, the observation was dropped. Cows leaving their herd on their calving date were assigned one day of follow-up.

The following herd-level variables were created from the cow-level data, for each herd and year of follow-up, and defined under the following groups of indicators:

4.2.1.0.1 Demographics indicators Mean herd size was computed as animal-years. Proportion of first lactation cows in herd was calculated as the ratio between the animal-years of first lactation cows and the total animal-years. The difference between the incidence of sales (reported culling reason: sale for milk) and the incidence of animals purchased gave the livestock sale indicator. Proportion of calvings occurring in the fall was computed as the ratio between the number of calvings between August and November and the total number of calvings for the year. Additional milk can be produced during these months despite the regulation imposed by the milk quota system in place in Québec.

4.2.1.0.2 Reproduction performance indicators Herd calving intervals were determined as the median time for the interval between a calving and the next one. Median days to first service was counted as the time between calving and first insemination. The 21-day pregnancy rate was computed as the incidence of pregnancies per 21 days (making allowance for a 50-day voluntary waiting period). For heifers, the one measure of reproductive performance was the mean age at first calving.

4.2.1.0.3 Production indicators Median real 305-day milk production (fat-protein corrected), fat, and protein yields from the production dataset were used. Peak milk production for heifers and cows was derived from monthly tests, as the maximum production within 90 days in milk. Milk production persistence was computed from the Wilmink equation (Wilmink, 1987) for primiparous and multiparous cows separately. Peak variation was defined as the variation coefficient of peak production for heifers and cows separately. Persistence variation was defined as the difference between the 75^{th} and the 25^{th} percentiles of the persistence indicators determined above for heifers and cows separately.

4.2.1.0.4 Health indicators The creation of health indicators was based on the computation of disease lactational incidence risk as recommended by Kelton et al. (1998): the ratio between the number of lactations with one (or more) cases of the disease and the number of lactations at risk. The incidences of the following diseases were computed: milk fever (MF; for all parities and parity 3 and greater), retained placenta (RP), endometritis (MET, as a reproductive health event occurring between 21 and 120 days after calving), displaced abomasum (DA, ratio of the number of lactations with first diagnosis of DA to the number of lactations by cows without a previous diagnosis of DA), cystic ovaries disease (COD), lameness, clinical mastitis, and dystocia (as the number of calvings with dystocia over the number of calvings). To get an appraisal of the sub-clinical cases present in the herd, an udder health index was created as the proportion of cows with a geometric mean of somatic cell count over 200,000 cells for their lactation. The somatic cell count was made available from the monthly test in the production dataset coming from the DHI. The mortality incidence was determined as well.

4.2.1.0.5 Culling rate indicators Three culling indicators were calculated for each herd and each year of follow-up, as the number of events per animal-year at risk. These three indicators were the overall culling rate (CR), culling rate by 60 days in milk (DIM; CR60), and dairy sale rate by 60 DIM (DS60). The rates were divided into the following groups: $< 25\%$, 25%–30%, 30%–35%, and $> 35\%$ for CR; $< 5\%$, 5%–10%, and $> 10\%$ for CR60; and no dairy sales, 0%–3%, and $> 3\%$ for DS60.

4.2.2 Data Analysis

Culling events and time at risk were counted by year, between 2001 and 2010. Culling incidences (overall, by 60 DIM, dairy sales by 60 DIM) for the entire cohort were computed using a generalized estimating equation (GEE) model (Højsgaard et al., 2006; Yan et al., 2004) with Poisson distribution, log link function, exchangeable correlation structure, and robust sandwich estimator, to take into account repeated measures within the herd.

The relationship between various herd indices separated into different groups was assessed with a Multiple Factor Analysis (MFA; Escofier et al., 1994). All groups of indicators were defined as above, with culling rate indicators used as supplementary variables, i.e. they were not used to calculate the factors, but were projected onto the active space (Lebart et al., 2006).

The MFA was done first with the groups of indicators clustered by year. The same MFA was then done while imputing missing values (Husson et al., 2013; Josse et al., 2012). If no difference between the two models and no effect of the year were present, the computed indices were averaged for each herd over their follow-up period and the final MFA was performed (mean for rates, weighted mean for proportions, and weighted medians for median based indicators). The number of factors used for the interpretation was determined based on a scree plot and the eigenvalues for each group (Cattell, 1966; Horn et al., 1979).

The relationship between groups of indicators were checked with the Lg (Escofier et al., 1994; Pagès, 2014) and RV (Escoufier, 1973) coefficients. The Lg coefficient is an indicator of multidimensionality: the larger Lg is, the more the two groups compared share a common inertia. RV is the Lg coefficient ‘normalized’ in [0,1], where 0 indicates orthogonality between the two groups and 1 homothety. The interest in representing simultaneously the groups was also assessed by looking at the ratio of the inter-inertia to the total inertia (Lebart et al., 2006). Close to 1, it confirms the 'common' character of a factor. If no relationship was found between the group of variables, a separate PCA was performed for each group of indicators.

The association between culling rates supplementary variables and an axis was tested with a test-value (Morineau, 1984). An absolute test-value of 2 means the corresponding mean difference has about 5 chances out of 100 of being reached or exceeded. However this value of 2 is very liberal in the presence of multiple testing, as we have here. No satisfying values are available though, and test-values should rather be seen as a way to classify supplementary modes by order of decreasing interest (Lebart et al., 2006).

All statistics were computed with R version 3.3.2 (R Core Team, 2015); packages geepack (Højsgaard et al., 2006) and FactoMineR (Lê et al., 2008).

4.3 Results

A total of 432,733 lactations from 156,409 cows (> 95% Holsteins) from 763 herds were available for analysis. The overall yearly culling incidence of the 763 herds was 0.32 cullings per cow-year at risk, 95% confidence interval (CI) [0.316, 0.325]. The dairy sale incidence was 0.032 sales per cow-year at risk [0.028, 0.036], and the culling incidence by 60 DIM was 0.082 cows culled per cow-year at risk [0.079, 0.084]. The variation in the overall culling incidence is shown in Figure 4.1. Descriptive statistics for the 30 indices and the culling rates are presented in Table 4.I. The yearly herd culling rates ranged from 11% to 53%.

4.3.1 Multiple Factor Analysis

There was no effect of the year of observation nor of the imputation of missing values. Hence, the computed indices were averaged for each herd over their follow-up period. After examination of the scree plot and eigenvalues, a two factor solution was chosen.

The explained variance for each axis from the MFA was very low (Table 4.II:

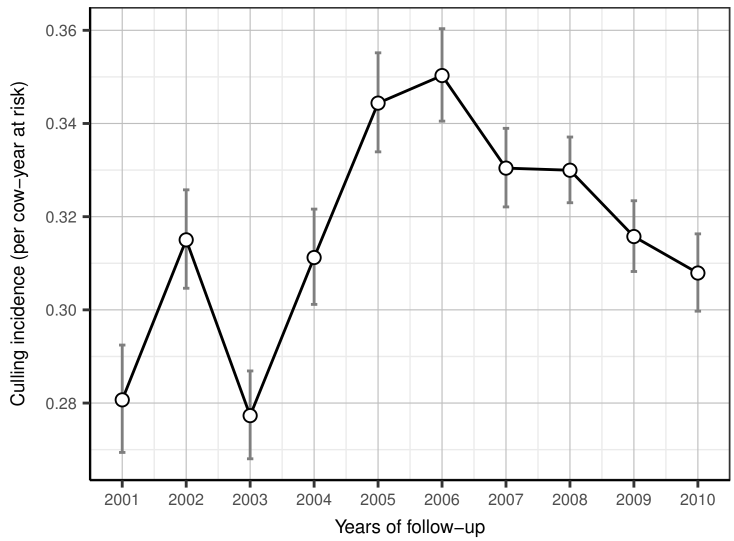

Figure 4.1 – Culling incidence (and 95% confidence interval) for each year of follow-up from generalized estimating equation (GEE) model.

13.7% for the first axis and 12.6% for the second). *Demographics* and *Production* groups of indicators had the largest inertia on the first axis (eigenvalues of 0.65 and 0.4, respectively), *Health* and *Reproduction* groups contributing little to this axis. On the other hand, *Reproduction* had the largest inertia on the second principal component (eigenvalue of 0.48) while *Production* and *Health* contributed equally to this axis (eigenvalues of 0.31 and 0.33, respectively) while *Demographics* did not contribute at all. Neither were the different groups well projected on each axis, as evidenced by the groups' squared cosines ranging from 0.02 to 0.15 on the first factor (0.01 to 0.18 on the second).

The four active groups and the supplementary one, *Culling*, are displayed in the two-dimensional space defined by the MFA's first two factors (according to their squared loadings, i.e. the importance of their association with the factor) (Figure 4.2). The groups' coordinates, between 0 and 1, indicate the percentage of inertia explained by the first factor (first dimension, horizontal axis) and the second factor (second dimension, vertical axis). *Demographics* and *Production* are found on the first axis, but none are strongly common to the first factor. Of the two, *Demographics* is the more discriminating between farms, especially according to their proportion of first lactation cows and their livestock sales (contributions of, respectively, 24.8% and 19.1% on the first axis). The other two active groups make a small contribution to this factor. The second factor results mainly from the group *Reproduction*. The illustrative group, *Culling*, is not linked to the second factor and only weakly to the first one. The inertia of the 5 groups of variables in relation to the first and second factors were low. Therefore the herds were poorly differentiated based on the common information brought by these groups of variables. Both the Lg and RV coefficients were very close to zero. The ratio of the inter-inertia to the total inertia is quite low on each axis as well (0.38 for first and 0.36 for the second axis).

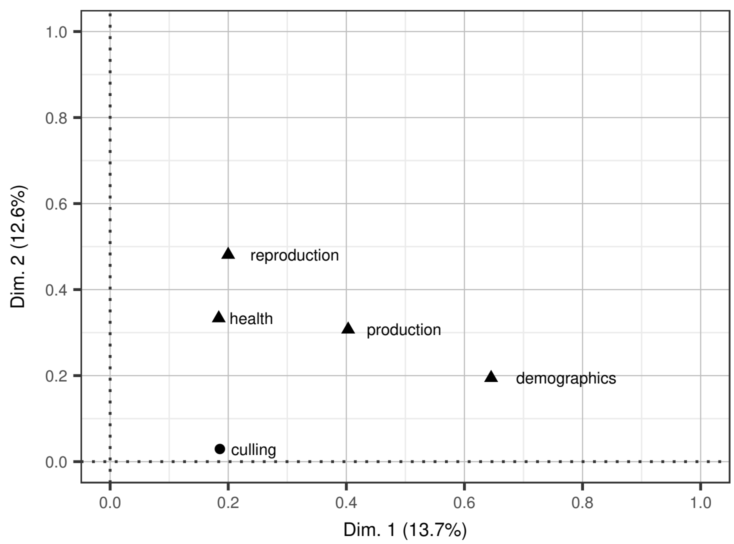

Figure 4.2 – Contribution of groups of indicators to the first two dimensions of the Multiple Factor Analysis (MFA), according to their squared loadings (triangles, active groups; circle, supplementary group).

The MFAs with the merged groups *Demographics/Production* and *Reproduction/Health* returned the same result of no relationship between the groups of variables. Hence, PCAs on each separate group were run to get more insight into each of these groups separately.

4.3.2 PCA

From the separate analyses by groups (PCA, Table 4.II), we could see that all groups are uni-dimensional, i.e. their inertia is mainly on a single axis, with the exception of *Demographics*. The component loadings, i.e. the position of the variables in the two-dimensional space, are shown in Figure 4.3 for each PCA.

4.3.2.0.1 Demographics The first factor has an eigenvalue of 1.2 (explained variance of 30.9%). The first axis is made of the two variables *Proportion of first lactation* and *Livestock sales*, while the second axis is made of *Proportion of calvings in the fall* and *Herd size*. We can note that both are orthogonal to each other. The first factor can be summarized as *Herd dynamics*, i.e. representing a modification in herd structure, and the second factor being the *Herd management*.

According to the test-value, only the highest CR mode was associated with the second axis (Table 4.III; a smaller herd size and lower proportion of calvings in the fall with a higher cull rate). But they are all strongly associated with the first axis, except the medium rate 30%–35%. The culling rate is associated with *Herd dynamics*, and the highest culling rates are also negatively associated with *Herd management*.

CR60 is associated with the first axis for the lowest and highest levels; and for all levels on the second axis but the lowest one.

DS60 is associated with the first axis, at all levels; and with the second axis for the lowest and highest rates.

4.3.2.0.2 Reproduction The first factor has an eigenvalue of 2.2 (explained variance: 53.9%). From Figure 4.3, the first axis is made of *Calving interval*, *Days to first service*, and *21-day pregnancy rate*; the second axis by *Age at first calving*. *Calving interval* and *21-day pregnancy rate* go in opposite directions, i.e. herds with higher 21-day pregnancy rates had shorter calving intervals. They also serviced the cows earlier. However, it is orthogonal with *Age at first calving*.

Regarding culling practices, the lowest and highest culling rates are associated

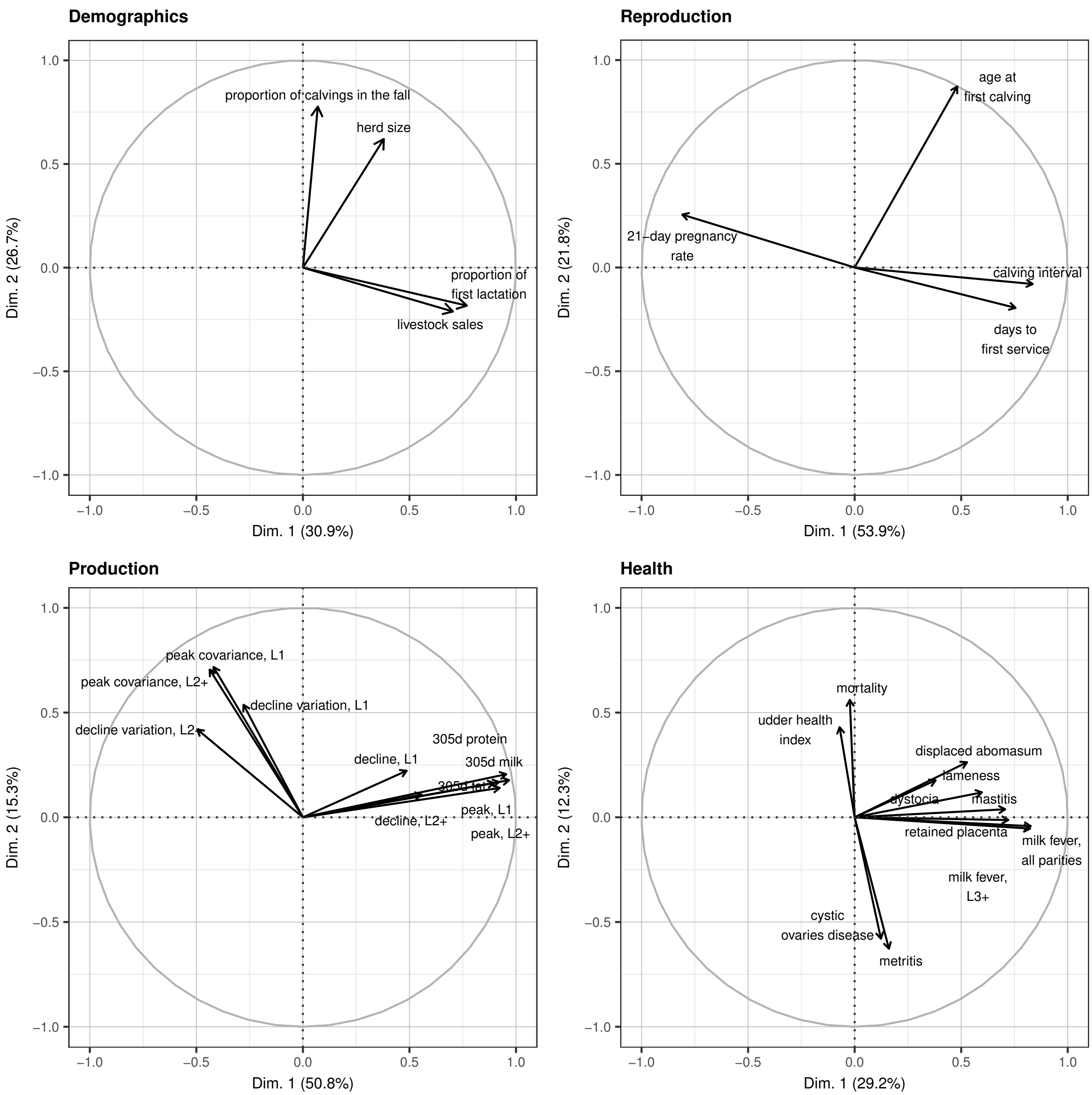

Figure 4.3 – First two dimensions of Principal Component Analyses (PCA) on each group of indicators. Vector of variable in direction of the highest value of this variable (305d, 305 days; L1, heifers; L2+, cows; L3+, parities 3 and greater).

with the first and second axis, i.e. lowest culling rates are found in herds with a delayed age at first calving, the highest 21-day pregnancy rate, the shortest calving interval, and vice versa (Table 4.IV).

The lowest CR60 is associated with the first axis only (lowest rates linked to longer calving intervals and lower pregnancy rates). The same can be said for DS60, but only for the second axis (no dairy sales associated with older age at first calving; more dairy sales with earlier age at first calving).

4.3.2.0.3 Production The first factor had an eigenvalue of 5.6 (explained variance of 50.8%). The first axis is made of *305-day milk*, *fat*, and *protein*, and *Peak heifer* (L1) and *cow* (L2+) production; and the second axis of *Peak heifer* (L1) and *cow* (L2+) *covariance* (but their quality of representation is not strong: low squared cosines of 0.52 and 0.5, respectively). Our focus is then mainly on the first axis, where herds can be distinguished based on their level of production (Figure 4.3).

The overall culling rates are weakly associated with the first axis. The highest and lowest 60 DIM rates are associated with this axis, with lower rates found in lower producing herds and higher rates in higher producing herds (Table 4.V).

4.3.2.0.4 Health The first factor has an eigenvalue of 3.2 (explained variance: 29.2%). The first axis is made of *MF* (all parities and parities 3 and greater, L3+), *DA*, *Lameness*, *RP*, and *Mastitis*. The second axis is made of *Metritis*, *COD*, and *Mortality*. We can note that *RP* and *Metritis*/*COD* are orthogonal: the highest RP incidence is not linked to the highest incidence of metritis and/or COD. However, only *MF* had a good quality of representation on the axes (squared cosine = 0.68).

The medium overall culling rate (30%–35%) was associated with the first axis (highest MF incidences). The lowest CR60 was associated with lower MF incidences (Table 4.VI).

4.4 Discussion

This study found an average culling rate of 32% over the 2001–2010 decade, a CR60 of 8.2%, and a DS60 of 3.2%. This overall culling rate is similar to the rates commonly found in North America (Radke et al., 2000). Lower culling rates are often reported in Europe (between 20% and 25%) (Esslemont et al., 1997; Mohd Nor et al., 2014; Sol et al., 1984; Whitaker et al., 2004) but Oler et al. (2012) recorded a 32% culling rate in Poland. In the United States, while Gardner et al. (1990) reported a 25% culling rate in California dairy herds in 1990, more recent studies by De Vries et al. (2010) as well as Dechow et al. (2008) found culling rates comparable to this study (32% and 30.7%, respectively). On the other hand, the US National Animal Health Monitoring System (2007) reported lower culling rates, ranging from 25% to 31.3% between 2001 and 2006. Culling rate definitions can vary across studies, and comparisons should be made with care. However, the large variation of culling rates between herds is constantly found across studies, and ours is no exception, with culling rates as low as 11% and as high as 53%. Still, the present study is the first to compute culling rates on such a large observational cohort, followed for 10 years. CR60 was similar to what was reported by Dechow et al. (2008), 7.6%. The dairy sale rate was also in the range reported in the literature (3% in Dechow et al. (2008), 4.1% in Mohd Nor et al. (2014), and 5.5% in US National Animal Health Monitoring System (2007)). The evolution of the culling rate over time showed a sharp decline in 2003. While Canada experienced its second bovine spongiform encephalopathy case in May 2003, it is hard to impute this rate drop solely to that event. Without data before 2001, it is difficult to determine whether the 2002 increase in culling was a trend or just a blip due to particular conditions. Nevertheless, we have to recognize that cull cattle prices were considerably reduced in 2003, potentially creating a positive environment for decreased culling rates.

We could not demonstrate the presence of specific profiles of herds based on reproduction, production, demographics, and health indicators but, on the contrary, we show the heterogeneity among Québec dairy herds for these contextual factors.

By considering each domain separately, profiles of herds emerged according to their population dynamics, population management, reproduction indicators, production, and milk fever incidence. Lower and higher cull rates could be linked to demographics and reproduction contextual variables, but not to the production and health variables. Production indicators however were associated with CR60 and DS60. The relationships between disease incidences and culling rates were weak.

Multiple factor analysis handles tables in which a set of observations is described by several sets of variables, each set having distinct meanings. The present results of the MFA demonstrate the heterogeneity among herds for the four groups of variables evaluated. The eigenvalues from a MFA are linkage indices between the associated factor and all the groups, where the maximum value, 4 (i.e. the number of groups, J), is obtained when one factor from the global analysis is confounded with the first factor from the separate analysis of each group. If the first eigenvalue is close to J, the first factor is common to all groups and is an important direction of inertia for each of them. This was clearly not the case here, and we could conclude there was little relationship between the groups. Each group's inertia being very low, the information brought by each group is very different. Previous studies already demonstrated that farmers' management style and attitude were more important then herd-level characteristics for farm performance (Bigras-Poulin et al., 1985; Tarabla et al., 1990). We have shown here that herds could not be clustered based on the combination of multiple selected herd-level variables. No relationships between groups of indicators could be highlighted and each group had to be considered separately. From the separate PCAs, relationships between culling rates and specific herd-level variables were limited to livestock sales, proportion of first lactation cows, herd size, proportion of calvings occurring in the fall, longer calving intervals and reduced 21-day pregnancy rates, increased days to first service, average age at first calving, and reduced milk fever incidence. Some of these relationships are expected, such as the relations between cull rate, CR60, DS60 and livestock sales and proportion of first lactation cows. Others were maybe less expected, for example, higher cull rates in herds with longer calving intervals, lower 21-day pregnancy rates, and higher average days to first service. Herds having difficulties to get their cows pregnant, or having worse reproductive performance, were more likely to remove their problematic animals. We also found that cull rates were associated with the herd's average age at first calving, i.e. higher cull rates were found in herds with early first calving and vice versa. The only contextual health variable associated with CR60 was the MF incidence (all parities, and third lactation and over), where herds with lower MF incidence had lower CR by 60 DIM.

For a cow, being fertile (De Vries et al., 2010; Schneider et al., 2007) and healthy (Beaudeau et al., 2000; Gröhn et al., 1998; Rajala-Schultz et al., 1999a) would generally allow her to stay longer in the herd. These associations were made at the cow-level and cannot be generalized to a collective relationship. Doing so would result in an atomistic fallacy (Diez Roux, 1998; Duncan et al., 1993). This bias arises from the presence of multiple levels of organization in the dataset, where a variable defined and measured at one level may belong to a different construct than its counterpart at another level. For example, regarding milk production performance, if herds can be distinguished based on these, it is not related to the herd culling rate despite milk production being a protective factor against culling for the cow (Gröhn et al., 1998; Rajala-Schultz et al., 1999c). Other factors are at play when looking at herd-level associations compared to cow-level ones (LeBlanc, 2010a). In particular, a human variable is introduced by the herd manager who's making economically-driven herd management decisions, resulting in a given herd culling rate. These decisions can result in a different cow-specific culling risk. Hence, constructs from a higher level can be important to understand variability at a lower level and vice versa, thus the appeal of multilevel models to explore the hierarchical structure of data. These multilevel models make use of random slopes, contextual variables, or both (Stryhn et al., 2014). Although a synthetic, composite, variable could not be identified to summarize the herds, we were able to determine several potential contextual variables of interest for dairy cow multilevel modelling, i.e. herd dynamics (herd size, proportion of first lactation cows), reproduction indicators (average age at first calving, 21-day pregnancy rate), herd average 305-day milk production, and MF incidence.

The herds were representative of Québec dairy herds using a monthly DHI service for individual cow milk recording, and a computerized data management system for reproduction and health management. Compared to Québec statistics on dairy herds [1], study herds had the same characteristics in terms of size, with slightly better milk production—200 kg over 305-day—and reproductive performance—shorter calving intervals and fewer days to first service in study herds. Compared to the *DSA Laitier* database, our study herds had also better 21-day pregnancy rate (18 vs 16). However our study herds followed exactly the same trends for each of the indices over the 10 years of follow-up as those from DHI and *DSA Laitier*. By using aggregated data, we assumed that we will have reduced measurement errors in the covariates, as they are based on averages (Guthrie et al., 2001; Prentice et al., 1995; Richardson et al., 2001). Also, it has been demonstrated that the effect of measurement errors on the PCA results in an increase in variability, not in bias (Hellton et al., 2014). Beyond measurement error, the construct referenced on the group-level data could be distinct from the one at the individual-level (Schwartz, 1994). With aggregated, group-level data we provided information on true group-level constructs, not just summaries of individual-level constructs (Diez Roux, 2004). The validity of the aggregated data is also related to the sample size of the data used to create them. By selecting herds larger than 30 animal-years, followed for three years, we increased our confidence in the validity of the aggregation.

4.5 Conclusion

This study provided the first description of Québec herd culling rates using 10 years of follow-up data. It demonstrated the heterogeneity of Québec dairy herds according to demographics, reproduction, production, and health indicators. However, it allowed determining profiles of herds according to specific domains independently. The identified contextual variables can be used in multilevel modelling of culling

1. Available online at `http://www.valacta.com/FR/Nos-publications/Pages/evolution-de-la-production-laitiere.aspx`

risk.

Conflict of interest

None.

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Table 4.I – Descriptive statistics (percentiles) of 763 herds for yearly indices (see description in text).

Variables	p5	p25	p50	p75	p95
Demographics indicators					
Herd size (animal-years)	32.6	39.3	48.9	62.3	100.4
Proportion of first lactation cows (%)	26.1	31.3	34	36.7	41.2
Proportion of livestock sales[1]	-7.1	-1.4	0.2	2.8	11.7
Proportion of calvings in the fall (%)[2]	28.4	32.8	35.4	38.4	43.1
Reproduction performance indicators					
Median calving interval (months)	12.3	12.6	12.9	13.2	13.7
Median days to first service	65	72.5	78	83.5	96.9
21-day pregnancy rate (calvings per 100 cows-21 days)	12.8	15.6	18	20.5	24.5
Mean age at first calving (months)	25	25.9	26.6	27.4	29.1
Production indicators					
Median 305-day milk production (kg)	7344.9	8559.8	9197.5	9780.8	10742.2
Median 305-day fat production (kg)	282.6	325	347	370.5	408
Median 305-day protein production (kg)	238.6	277	298	316	347
Peak milk production[3] (kg)—Heifers	26.1	30	31.9	33.8	36.3
Persistency[4]—Heifers	94.3	95	95.5	96	96.4
Peak milk production variation coefficient (%)—Heifers	11.7	13.4	14.7	16.4	19.4
Milk production persistence variability[5]—Heifers	1.6	2	2.3	2.6	3.1
Peak milk production[3] (kg)—Cows	33.9	38.7	41.7	44.3	48.3
Persistency[4]—Cows	92.4	93.2	93.5	93.9	94.4
Peak milk production variation coefficient (%)—Cows	12.9	14.6	15.9	17.4	21
Milk production persistence variability[5]—Cows	1.9	2.2	2.4	2.7	3.2
Health indicators					
Milk fever incidence[6]—All parities	0	1.2	2.4	4.6	8.7
Milk fever incidence[6]—Parities 3+	0	2.4	5	9.4	17.9
Retained placenta incidence[6]	0.4	2	4.1	6.8	11.6
Metritis incidence[6]	0.5	1.7	3	5.1	10.9
Displaced abomasum incidence[6]	0	1.3	2.7	4.6	8.3
Cystic ovaries disease incidence[6]	2	5.7	9.1	13.8	20.6
Lameness incidence[6]	0	1	3	6.8	20.1
Mastitis incidence[6]	0.8	3.7	7.8	16	31.5
Dystocia incidence[6]	0	0.5	1.6	3.8	8.9
Mortality[7]	0.9	2.5	3.9	5.9	11.2
Udder health index (%)[8]	10.4	15.7	20.1	25.3	33.3
Culling rate (%)	21.2	27.3	31.1	35.3	42.7
Culling rate by 60 DIM[9] (%)	2.7	5.2	7.3	9.6	14
Dairy sales by 60 DIM[9] (%)	0	0	0.3	1.3	6

[1] Sales minus purchase per 100 cow-years, [2] From August to November,
[3] Maximum production within 90 days in milk, [4] Percent milk decline by month, [5] 75 to 25 percentile,
[6] Affected lactations per 100 lactations at risk, [7] Per 100 cow-years, [8] Proportion of cows over 200 000 cells,
[9] Days in milk

Table 4.II – Eigenvalues and explained variances (%) decomposed on the first two factors and by group of indicators, for Principal Component Analyses on each group of indicators (top) and for Multiple Factor Analysis (bottom).

	Global inertia	Factor 1		Factor 2	
		Eigenvalue	% variance	Eigenvalue	% variance
PCA demographics	4	1.24	30.93	1.07	26.67
PCA reproduction	4	2.15	53.86	0.87	21.76
PCA production	11	5.59	50.82	1.69	15.34
PCA health	11	3.21	29.16	1.35	12.28
MFA	10.49	1.43	13.65	1.32	12.55
demographics	3.23	0.65	45.05	0.19	14.79
reproduction	1.86	0.20	13.96	0.48	36.54
production	1.97	0.40	28.15	0.31	23.34
health	3.43	0.18	12.84	0.33	25.33

PCA, Principal Component Analysis; MFA, Multiple Factor Analysis.

Table 4.III – Test-values for supplementary variables *Culling*—Principal Component Analysis on *Demographics* indicators. An absolute test-value of 2 means the corresponding mean difference has about 5 chances out of 100 to be reached or exceeded.

		Dim. 1	Dim. 2
Culling rate (%)	<25	-5.83	1.88
	[25,30)	-4.31	0.83
	[30,35)	1.20	0.81
	>35	7.86	-3.24
Culling rate by 60 DIM (%)	[0,5)	-4.62	-0.40
	[5,10)	-1.62	2.20
	>10	6.63	-2.24
Dairy sales by 60 DIM (%)	none	-12.39	3.73
	[0,3)	3.68	-0.05
	>3	12.52	-4.88

DIM, days in milk.

Table 4.IV – Test-values for supplementary variables *Culling*—Principal Component Analysis on *Reproduction* indicators. An absolute test-value of 2 means the corresponding mean difference has about 5 chances out of 100 to be reached or exceeded.

		Dim. 1	Dim. 2
Culling rate (%)	<25	-2.22	5.30
	[25,30)	-2.74	0.26
	[30,35)	0.77	-1.20
	>35	3.78	-3.33
Culling rate by 60 DIM (%)	[0,5)	2.45	0.82
	[5,10)	-0.91	0.08
	>10	-1.39	-0.93
Dairy sales by 60 DIM (%)	none	-1.21	2.29
	[0,3)	0.44	-0.98
	>3	1.13	-1.99

DIM, days in milk.

Table 4.V – Test-values for supplementary variables *Culling*—Principal Component Analysis on *Production* indicators. An absolute test-value of 2 means the corresponding mean difference has about 5 chances out of 100 to be reached or exceeded.

		Dim. 1	Dim. 2
Culling rate (%)	<25	-1.22	-2.10
	[25,30)	-2.11	-1.95
	[30,35)	1.56	-0.05
	>35	1.49	3.74
Culling rate by 60 DIM (%)	[0,5)	-2.75	-3.88
	[5,10)	0.24	0.92
	>10	2.49	2.82
Dairy sales by 60 DIM (%)	none	-7.03	1.74
	[0,3)	2.06	-1.36
	>3	7.13	-0.88

DIM, days in milk.

Table 4.VI – Test-values for supplementary variables *Culling*—Principal Component Analysis on *Health* indicators. An absolute test-value of 2 means the corresponding mean difference has about 5 chances out of 100 to be reached or exceeded.

		Dim. 1	Dim. 2
Culling rate (%)	<25	-1.40	-3.58
	[25,30)	-1.17	0.70
	[30,35)	2.52	0.61
	>35	-0.34	1.58
Culling rate by 60 DIM (%)	[0,5)	-3.35	-1.91
	[5,10)	2.05	0.37
	>10	0.94	1.50
Dairy sales by 60 DIM (%)	none	1.49	4.18
	[0,3)	-1.10	-1.73
	>3	-0.81	-3.72

DIM, days in milk.

CHAPITRE 5

CONTEXTUAL HERD FACTORS ASSOCIATED WITH COW CULLING RISK IN QUÉBEC DAIRY HERDS : A MULTILEVEL ANALYSIS

Denis Haine[1], Hector Delgado[2], Roger Cue[2], Asheber Sewalem[3], Kevin Wade[2], René Lacroix[4], Daniel Lefebvre[4], Julie Arsenault[1], Émile Bouchard[1], Jocelyn Dubuc[1]

[1]Faculté de médecine vétérinaire, Université de Montréal, 3200 rue Sicotte, C.P.5000, St-Hyacinthe, Québec, Canada J2S 7C6
[2]Department of Animal Science, McGill University, 111 Lakeshore Road, Ste-Anne-de-Bellevue, Québec, Canada H9X 3V9
[3]Guelph Food Research Centre, Agriculture and Agri-Food Canada, 93 Stone Road West, Guelph, Ontario, Canada N1G 5C9
[4]Valacta Inc., 555 boul. des Anciens-Combattants, Ste-Anne-de-Bellevue, Québec, Canada H9X 3R4

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Contributions

	Travail de recherche : planification	réalisation	interprétation	contrôle	Manuscrit : collaboration à la rédaction	approbation version finale
D. Haine	X	X	X		X	X
H. Delgado		X				X
R. Cue	X					X
A. Sewalem	X					X
K. Wade	X					X
R. Lacroix		X				X
D. Lefebvre		X				X
J. Arsenault			X	X	X	X
É. Bouchard	X					X
J. Dubuc	X		X	X	X	X

Abstract

Several health disorders, such as milk fever, displaced abomasum, and mastitis, as well as impaired reproductive performance, are known risk factors for the removal of affected cows from a dairy herd. While cow-level risk factors are well documented in the literature, herd-level associations have been less frequently investigated. The objective of this study was to investigate the effect of cow- and herd-level determinants on variations in culling risk in Québec dairy herds: whether herd influences a cow's culling risk. For this, we assessed the influence of herd membership on cow culling risk according to displaced abomasum, milk fever, and retained placenta.

A retrospective longitudinal study was conducted on data from dairy herds in the Province of Québec, Canada, by extracting health information events from the dairy herd health management software used by most Québec dairy producers and their veterinarians. Data were extracted for all lactations starting between January 1st and December 31st, 2010. Using multilevel logistic regression, we analysed a total of 10,529 cows from 201 herds that met the inclusion criteria. Milk fever and displaced abomasum were demonstrated to increase the cow culling risk. A minor general herd effect was found for the culling risk (i.e. an intra-class correlation of 1.0% and median odds ratio [MOR] of 1.20). The proportion of first lactation cows was responsible for this significant, but weak herd effect on individual cow culling risk, after taking into account the cow-level factors. On the other hand, the herd's average milk production was a protective factor. The planning and management of forthcoming replacement animals has to be taken into consideration when assessing cow culling risks and herd culling rates.

Keywords culling, dairy cow, multilevel, contextual.

5.1 Introduction

Several health disorders, such as milk fever, displaced abomasum, and mastitis, as well as impaired reproductive performance, are known risk factors for the subsequent removal from a dairy herd of the affected animals (Beaudeau et al., 2000; De Vries et al., 2010; Gröhn et al., 1998; Rajala-Schultz et al., 1999a). High culling rates can sometimes be viewed as a sign of management failure (Eicker et al., 2003) despite the lack of consensus on an acceptable culling rate, each herd having an optimal culling rate for its own management and dynamics (Rapnicki et al., 2003). Nevertheless, culling rates greater than 30% are common in American and Canadian dairy herds (Fetrow, 1987; Radke et al., 2000; Smith et al., 2000), despite improvements in cows' health and herd productivity (LeBlanc et al., 2006; Mee, 2007).

While cow-level culling risk factors are well documented in the literature, herd-level associations have been less frequently investigated. But even without having this specific objective in mind, a significant herd effect on cow culling risk was reported by some studies (Beaudeau et al., 1995; Emanuelson et al., 1998; Gröhn et al., 1998). The farmer's management style and attitude were shown to contribute significantly to the variation in farms' performance (Bigras-Poulin et al., 1985; Tarabla et al., 1990). It is also recognized that group- or herd-level variables can affect or modify individual-level outcomes independently of the characteristics of the individuals (Diez Roux, 1998). Therefore we could hypothesize that several herd characteristics can modify the cow culling risk, such as, for example, the availability of nulliparous heifers and milk quotas, the farmer's attitude towards risk and uncertainty, the milk and beef market, etc. (Beaudeau et al., 2000) Hence it would be interesting to integrate the population context into individual-level analyses to untangle the relationships between the variables at various levels (Guthrie et al., 2001), which has not yet been done in dairy cow culling research. Multilevel models achieve this goal by decomposing the variability across hierarchical levels (Stryhn et al., 2014).

The objective of this study was to investigate the effect of herd-level determinants on variations in cow culling risk in Québec dairy herds, i.e. to examine whether, over and above cow factors, herd influences a cow's culling risk. To this end, we assessed and used the effect of retained placenta (RP), milk fever (MF), and displaced abomasum (DA) on culling.

5.2 Materials and methods

5.2.1 Dataset

A retrospective longitudinal study was conducted using data from dairy herds in the Province of Québec, Canada, by extracting health information events from *DSA Laitier* (DSAHR Inc., Saint-Hyacinthe, QC, Canada), the dairy herd health management software used by more than half of Québec producers and their veterinarians. We had access to a purposive sample of all lactations taking place between January 1st, 2001 and December 31st, 2010 (249,536 cows from 3735 herds), keeping herds that had a minimum of three consecutive years of data with *DSA Laitier* and for which at least one culling was recorded over this period. From this dataset, we extracted the data for all lactations starting between January 1st and December 31st, 2010. If a cow had more than two lactations starting in 2010, only the first was kept. Production data were obtained from the sole Québec dairy herd improvement (DHI) service provider (Valacta, Sainte-Anne-de-Bellevue, QC, Canada). The health and production data were matched based on herd- and cow-level identification. If that was not successful, further matching within herd was tried, based on birth date, calving dates, and health and production history. Only herds for which at least 95% of the lactations from the health dataset could be matched with data from the production dataset were kept (42,809 cows from 714 herds). Herds with fewer than 30 animals, for which more than 30% of the DHI monthly tests were missing, and with a 2010 lactational incidence that was less than 3% for RP, and 1% for either MF or DA, were removed to avoid herds with gross under-reporting. Cows with a calving interval, or the interval between the last calving and the end of data, longer than 580 days were censored at their last calving date. If this censoring resulted in their first calving date, the observation was dropped.

The primary outcome, culling, was defined as a cow's being removed from the herd, i.e. due to death, sold to another herd, or sent for slaughter. A directed acyclic graph (DAG, Figure 5.1) was used to identify a minimal set of measured confounders for each disease studied (RP, MF, DA) (Greenland et al., 1999; Shrier et al., 2008), with the help of DAGitty software (Textor et al., 2011). Its construction was based on empirical knowledge from the findings of previous studies and on the authors' educated knowledge. This resulted in a single common DAG for the three diseases, with the following confounders considered: clinical mastitis, parity (continuous), calving season (January to July and August to December), dystocia, and abortion.

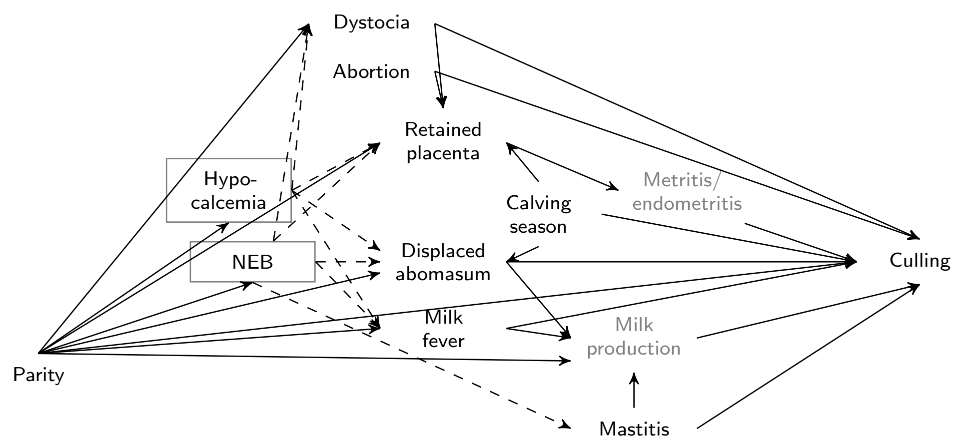

Figure 5.1 – Directed acyclic graph (DAG) for the effect of retained placenta, milk fever, and displaced abomasum on culling (grey: intermediate variables; boxes/dashed lines: unobserved [latent] variables; NEB: negative energy balance).

Six variables describing herd characteristics were included as contextual variables based on Haine et al. (in preparation): herd size, proportion of primiparous cows, average age at first calving, average milk production, milk fever incidence, and pregnancy rate.

5.2.2 Data Analysis

The data were analysed using a two-level logistic regression model with cows (first level) nested within herds (second level). The independent influence of cow factors and herd factors on the herd variance of culling was assessed using different models. We first estimated an 'empty' model (Model 1) with no variables entered and which only included a random intercept. We then adjusted the random intercept by adding cow-level factors in Model 2. Herd-level predictors (Model 3) were added to Model 2 to determine whether the cow-level differences were explained by herd characteristics (Merlo et al., 2005).

The random inter-herd variability was estimated by the herd-level variance, the intra-cluster correlation coefficient (ICC), and the median odds ratio (MOR). The ICC was calculated based on the latent response formulation as follows:

$$\frac{\sigma_z^2}{\sigma_z^2 + \pi^2/3} \times 100 \tag{5.1}$$

where σ_z^2 is the herd variance (Goldstein et al., 2002; Snijders et al., 2012). The ICC indicates the fraction of the total outcome variability that is attributable to the herd level and provides a measure of the within-herd homogeneity. A lower ICC indicates a lower likelihood of cows' sharing herd experiences. However, the ICC can be difficult to interpret with binary outcomes, as the partition of the variance between the different levels does not have the intuitive interpretation of a linear model (Goldstein et al., 2002). Therefore we also calculated the MOR, defined as the median value of the odds ratio between the herd at highest risk (higher culling rate) and the herd at lowest risk when randomly picking out two herds (Larsen et al., 2000). The MOR can be conceptualized as the increased risk (in median) that a cow would have if moved to a herd with a higher risk. It is statistically independent of the prevalence of culling and is also the most appropriate indicator for measuring the variation for dichotomous outcomes compared to ICC, which varies as a function of the prevalence and has serious interpretational drawbacks for binary responses (Merlo et al., 2006). The values of MOR are always ≥ 1. If the MOR is equal to 1, then there is no variation in the probability of being culled between herds, whereas a value greater than 1 indicates that there is a variation in the probability of being culled between herds—the larger the odds ratio (OR), the greater the variation (Larsen et al., 2005; Merlo et al., 2006). In addition, we also calculated the percentage of proportional change in variance (PCV) between two consecutive models to examine the extent to which the variables explain the variation in culling across herds.

The culling incidence was computed using a generalized estimating equation (GEE) model (Højsgaard et al., 2006; Yan et al., 2004) with Poisson distribution, log link function, exchangeable correlation structure, and robust sandwich estimator.

The parameters for the multilevel logistic regression models were estimated using Markov Chain Monte Carlo (MCMC), implemented using the Stan (Carpenter et al., in press) modelling language through the rstan (Stan Development Team, 2016) interface to R (R Core Team, 2015). This software implements Hamiltonian MCMC using the 'No U-turn' sampler (Hoffman et al., 2014), an MCMC algorithm that avoids random walk behaviour by using the gradient of the log-posterior (Neal, 2011). Each MCMC sample used four sampling chains with 100 burn-in samples followed by 900 monitored samples. We checked for evidence of non-convergence using trace plots and the chain convergence indicator $\hat{R}$ (Gelman et al., 2014). The model adjustments were assessed using the Watanabe–Akaike Information Criterion (WAIC; Watanabe, 2010). The models were run under the Amazon EC2 cloud-computing environment (one node with a quad-core Intel(R) Xeon(R) CPU E5-2670 v2 and Ubuntu Server 14.04 LTS 64-bit operating system). The effect of potential selection bias was checked with the R episensr package in a probabilistic framework (Haine, 2016). Selection odds ratios were computed for RP, MF, and DA based on the selection proportion for each exposure from the non-selected observations of the database (Lash et al., 2009). We assumed that the bias parameters were drawn from a trapezoidal distribution with minimum, lower mode, upper mode, and maximum equal to the selection OR minus 0.25, minus 0.2, plus 0.2, and plus 0.25, respectively. We used 100,000 repetitions to randomly sample the selection OR to obtain estimates of the back-calculated ORs for comparison with the original, crude ORs.

5.3 Results

Table 5.I presents the characteristics of the 10,529 cows from 201 herds that met the inclusion criteria. The median herd lactational incidence risks were 4.2%, 3.4%, and 7.1% for DA, MF, and RP, respectively. Herd sizes ranged from 31.9 to 302.9 cow-years (median: 58.1). Information on breed was sparse in the database, but we estimated that at least 90% of the cows were Holsteins. The culling incidence rate and 95% confidence interval (CI) were 30.3 culled cows per 100 cow-year [28.8–31.8].

Table 5.I – Characteristics of cows by culling status (201 herds).

	Non-culled $N = 7{,}991$	Culled $N = 2{,}538$	Total $N = 10529$
Parity			
1	2,609 (33%)	607 (24%)	3216 (31%)
2	2,082 (26%)	472 (19%)	2554 (24%)
3	1,458 (18%)	456 (18%)	1914 (18%)
4+	1,842 (23%)	1,003 (40%)	2845 (27%)
Age at first calving (months)			
< 24	1,115 (15%)	347 (15%)	1462 (15%)
24–26	3,270 (43%)	940 (41%)	4210 (43%)
26–28	1,836 (24%)	582 (25%)	2418 (24%)
> 28	1,363 (18%)	437 (19%)	1800 (18%)
305-day milk production, kg (SD)[1]	9865(±1919)	9875(±1957)	9866(±1921)
Milk fever	286 (4%)	219 (9%)	505 (5%)
Displaced abomasum	339 (4%)	145 (6%)	484 (5%)
Dystocia	635 (8%)	290 (11%)	925 (9%)
Abortion	158 (2%)	125 (5%)	283 (3%)
Retained placenta	592 (7%)	244 (10%)	836 (8%)
Calved, August to December	2,878 (36%)	945 (37%)	3823 (36%)

[1]Mean, based on real production; SD = standard deviation

Table 5.II gives the OR and their 95% credible intervals (CrI) for the cow-level and contextual (herd-level) characteristics from the three models used. With cow- and herd-level variables controlled for, there was no difference between cows having or not RP on the risk of being culled with an OR and 95% CrI of 1.12 [0.96–1.31]. The two other diseases, MF and DA, were significantly associated with culling (OR and CrI of 1.85 [1.52–2.24] and 1.31 [1.07–1.62], respectively). The probability of a cow's being culled increased with parity (OR = 1.23 [1.19–1.26]). With the exception of calving season, all other cow-level confounding variables had a significant direct

effect on culling. Cows having clinical mastitis had a higher probability of being culled, by about 40%. Dystocia and abortion also increased the odds of culling. Two herd-level variables showed a significant effect: the proportion of first lactation cows in the herd, and the average herd milk production. Over and above the cow characteristics (presence of RP, MF, DA, clinical mastitis, dystocia or abortion, parity, and time of calving), being in a herd with a large proportion of primiparous cows increased a cow's probability of being culled (OR = 1.35 [1.16–2.59]). Similarly, a cow in a relatively high producing herd has a slightly lower probability of being culled (OR = 0.83 [0.71–0.98]). However, the relationship is less clear in very high producing herds (top quartile of herd average production in Table 5.II; OR = 0.89 [0.76–1.05]). The associations between the cow variables and culling were rather similar in all models (i.e. 2 and 3).

In Model 1 (the empty model), there was a significant variation in the log odds of culling across herds ($\sigma^2 = 0.038$, 95% CrI 0.014–0.07). According to the ICC implied by the estimated intercept component variance, 1.0% of the total cow differences in culling risk were at the herd level. Model 2 indicates that over and above the cow characteristics only 1.4% of the total cow differences in the propensity of being culled were at the herd level. Variations across herds remained statistically significant, even after controlling for cow-level and herd-level factors in the final Model 3, thereby giving credence to the use of multilevel modelling to account for herd variations. In Model 2, ICC and MOR were weak (1.4% and 1.25, respectively) which indicate that the herd captures some context for understanding a cow's probability of being culled. Taking into account the individual characteristics of the cows in Model 2 increased the herd variance. According to the proportional change in variance, about 21% of the variance in the log odds of culling across the herds were explained by the herd-level factors (Model 3).

The MOR results also confirmed the evidence of a herd contextual phenomena modifying the likelihood of a cow's being culled. In the median case, if a cow is moved to a herd with a greater risk of culling, the OR will be 1.20, which suggests a limited heterogeneity between herds. Controlling for cow-level factors increased

Table 5.II – Multilevel logistic models showing variance, cow- and herd-level predictors for retained placenta, milk fever, and displaced abomasum (n = 10,529; 201 herds).

	Model 1[a]		Model 2[b]		Model 3[c]	
	OR	95% CrI	OR	95% CrI	OR	95% CrI
Fixed effects						
Cow level						
Retained placenta			1.12	0.94, 1.32	1.12	0.96, 1.31
Milk fever			1.85	1.53, 2.24	1.85	1.52, 2.24
Displaced abomasum			1.31	1.06, 1.59	1.31	1.07, 1.62
Clinical mastitis			1.40	1.24, 1.58	1.39	1.23, 1.57
Parity			1.22	1.19, 1.25	1.23	1.19, 1.26
Calving, August to December			1.09	0.99, 1.19	1.09	0.99, 1.2
Dystocia			1.59	1.37, 1.84	1.59	1.36, 1.85
Abortion			2.81	2.2, 3.61	2.81	2.2, 3.63
Herd level						
Herd size						
1st quartile (smallest)					Ref.	
2nd quartile					1.03	0.86, 1.24
3rd quartile					1.04	0.87, 1.24
4th quartile (largest)					1.02	0.86, 1.22
Proportion of primiparous						
1st quartile (lowest)					Ref.	
2nd quartile					1.13	0.96, 1.33
3rd quartile					1.22	1.03, 1.44
4th quartile (highest)					1.35	1.16, 1.59
Average age at first calving						
1st quartile (youngest)					Ref.	
2nd quartile					1.09	0.93, 1.28
3rd quartile					1.08	0.91, 1.27
4th quartile (oldest)					1.01	0.85, 1.2
Average milk production						
1st quartile (lowest)					Ref.	
2nd quartile					0.83	0.71, 0.98
3rd quartile					0.83	0.71, 0.98
4th quartile (highest)					0.89	0.76, 1.05
Milk fever incidence						
1st quartile (lowest)					Ref.	
2nd quartile					0.91	0.78, 1.07
3rd quartile					1.00	0.85, 1.18
4th quartile (highest)					1.00	0.85, 1.18
Pregnancy rate						
1st quartile (lowest)					Ref.	
2nd quartile					1.06	0.9, 1.25
3rd quartile					1.02	0.86, 1.2
4th quartile (highest)					1.04	0.88, 1.23
Random effect						
Variance	0.038	0.014, 0.07	0.054	0.025, 0.09	0.043	0.013, 0.079
PCV (%)			43		−21	
ICC (%)	1.0	0.4, 1.9	1.4	0.7, 2.4	1.1	0.4, 2.1
MOR	1.20	1.12, 1.29	1.25	1.16, 1.33	1.22	1.12, 1.31
WAIC	11612		11184		11192	
WAIC change			−429		9	

OR, odds ratio; CrI, credible interval; PCV, proportional change of herd variance; ICC, intraclass correlation coefficient; MOR, median odds ratio; WAIC, Watanabe-Akaike information criteria.
[a] Empty model; [b] with cow-level variables; [c] with contextual variables.

the unexplained heterogeneity between herds to an MOR of 1.25. The unexplained herd heterogeneity decreased to 1.22 when all the factors were controlled for in the final Model 3. Thus, between herd variations in the likelihood of being culled are present, but these variations are small.

In assessing the model adjustment, we observed reduced WAIC values after including contextual-level variables. All models converged quickly and every $\hat{R}$ was below 1.01.

Selection ORs were 1.0, 1.08, and 0.96 for RP, DA, and MF, respectively. Adjusted crude ORs were equivalent to the non-adjusted ones.

5.4 Discussion

It is usually acknowledged that RP has no effect by itself on culling likelihood (Dubuc et al., 2011; Gröhn et al., 1998), even if some studies report it as a risk factor (Beaudeau et al., 1994). Rather, it is a risk factor for metritis and endometritis (LeBlanc, 2008), resulting in negative effects on reproductive performance (Dubuc et al., 2010; Fourichon et al., 2000; Gröhn et al., 2000). We demonstrated here the non-significant total effect of RP on culling risk. On the other hand, DA and MF are known risk factors for culling (Beaudeau et al., 1994; Gröhn et al., 1998; Hayes et al., 2012), and this study was no exception. More interesting was the exploration of a potential herd contextual effect on the culling risk. Although we found a significant variation between herds, this observed general contextual effect was fairly small (i.e. 1.0%). The addition of the contextual characteristics explained 21% of the herd variance, but variance was small (i.e. $\sigma^2 = 0.043$). Therefore it explains a substantial amount of a small effect. However, as the ICC and the partition of variance between different levels do not have the same intuitive interpretation as in linear models (Goldstein et al., 2002), we can refer to the MOR for exploring herd variation. None of the MOR credible intervals for the various models included 1. So there was a herd effect on culling rate. However, the herd effect was limited, as illustrated by a low MOR of 1.22. Even if small, we found a positive association between the selected herd characteristics and cow culling, over and above the cow's individual risk, possibly resulting from the pressure applied by the incoming flow of heifers on the herd size to remain constant. On the other hand, average herd milk production served as a protective factor for cow culling risk. However, when reaching a certain production threshold, the need to produce in these high-producing herds establishes an increasing pressure on the cows.

Replacement heifers are generally raised on farms in the Québec dairy herd management system. For a herd with good reproductive performance (i.e. 13 month calving interval) and heifer rearing program (i.e. low mortality, first calving around 24 months of age), around 40% of the herd will have a female calf reaching the milk production stage (Eicker et al., 2003). In other words, a herd culling rate of 40%. All herd managers therefore face the same decision: a choice has to be made between the next heifers to come into the herd, and the least profitable cow. Having little variation between herds (i.e. cow culling risk being rather uniform across herds), implies there is no specific, target, herd for lowering the herd culling rate. Once individual risk factors are managed for the cows, all herds would benefit from a comprehensive evaluation of the replacement heifer strategy. However, even though the herd variation was small, a relatively large amount of variation was still not explained by the contextual variables introduced in the model. Other factors might be at play, including dairy producers' perceptions of risk, and personal management preferences and styles (Bigras-Poulin et al., 1985).

The herds were representative of Québec dairy herds using a monthly DHI service for individual cow milk recording, and a computerized data management system for reproduction and health management. The incidences of DA, MF, and RP in this study were in line with what has been reported previously in the literature (Dubuc et al., 2010; Fleischer et al., 2001; Kelton et al., 1998). The herds were selected based on the availability of comprehensive health event records. If under-reporting bias is then minimized, a selection bias could have been introduced. By comparing the selection probability within levels of the exposure, the probabilistic sensitivity analysis gave about the same ORs and confidence intervals. We therefore have good confidence in the validity of our results.

5.5 Conclusion

We found a significant but limited herd effect on individual cow culling risk. Any attempt to manage the cull rate with the objective of decreasing it will have to take into account the improvement of both cow and herd health, including reproduction management and milk production planning and quality assessment. However the incoming flow of heifers should not be forgotten, i.e. planning and managing the forthcoming replacement animals.

Conflict of interest

None.

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CHAPITRE 6

CULLING FROM THE COW'S PERSPECTIVE—A MARGINAL STRUCTURAL COX MODEL TO DETERMINE THE EFFECT OF CLINICAL MASTITIS ON QUÉBEC DAIRY COW CULLING RISK

DENIS HAINE[1], HECTOR DELGADO[2], ROGER CUE[2], ASHEBER SEWALEM[3], KEVIN WADE[2], RENÉ LACROIX[4], DANIEL LEFEBVRE[4], JULIE ARSENAULT[1], ÉMILE BOUCHARD[1], JOCELYN DUBUC[1]

[1]Faculté de médecine vétérinaire, Université de Montréal, 3200 rue Sicotte, C.P.5000, St-Hyacinthe, Québec, Canada J2S 7C6
[2]Department of Animal Science, McGill University, 21 111 Lakeshore Road, Ste-Anne-de-Bellevue, Québec, Canada H9X 3V9
[3]Guelph Food Research Centre, Agriculture and Agri-Food Canada, 93 Stone Road West, Guelph, Ontario, Canada N1G 5C9
[4]Valacta Inc., 555 boul. des Anciens-Combattants, Ste-Anne-de-Bellevue, Québec, Canada H9X 3R4

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Contributions

	Travail de recherche :				Manuscrit :	
	planification	réalisation	interprétation	contrôle	collaboration à la rédaction	approbation version finale
D. Haine	X	X	X		X	X
H. Delgado		X				X
R. Cue	X					X
A. Sewalem	X					X
K. Wade	X					X
R. Lacroix		X				X
D. Lefebvre		X				X
J. Arsenault			X	X	X	X
É. Bouchard	X					X
J. Dubuc	X		X	X	X	X

Abstract

Health disorders, such as milk fever, displaced abomasum, or retained placenta, as well as poor reproductive performance, are known risk factors for culling in dairy cows. Clinical mastitis (CM) is one of the most influential culling risk factors. However the culling decision could be based either on the disease status or on the current milk yield, milk production being a significant confounder when modelling dairy cow culling risk. But milk yield (and somatic cell count) are time-varying confounders, which are also affected by prior CM and therefore lie on the causal pathway between the exposure of interest, CM, and the outcome, culling. Including these time-varying confounders could result in biased estimates. A marginal structural model (MSM) is a statistical technique allowing estimation of the causal effect of a time-varying exposure in the presence of time-varying covariates without conditioning on these covariates. The objective of this paper is to estimate the causal effect on culling of CM occurring between calving and 120 days in milk, using MSM to control for such time-varying confounders affected by previous exposure. A retrospective longitudinal study was conducted on data from dairy herds in the Province of Québec, Canada, by extracting health information events from the dairy herd health management software used by most Québec dairy producers and their veterinarians. The data were extracted for all lactations starting between January 1st and December 31st, 2010. A total of 2999 heifers and 6455 cows from 191 herds met the inclusion criteria and were used in the analysis.

The estimated CM causal hazard ratios were 1.45 [1.09–1.92] and 1.49 [1.26–1.76] for heifers and cows, respectively. Compared with estimates from the standard adjusted model, estimates from the MSM were 19% lower for heifers and 29% lower for cows. Our findings confirm that CM was a risk factor for culling, but with a reduced effect compared to previous studies, which did not properly control for the presence of time-dependent confounders such as milk yield and somatic cell count. Heifers and cows experienced the same risk for CM but milk production had less influence on culling risk in heifers than cows.

Keywords culling, dairy cow, bias, confounding, time-varying, marginal structural model, causal inference, survival.

6.1 Introduction

Health disorders, such as milk fever, displaced abomasum, or retained placenta (Beaudeau et al., 2000; Rajala-Schultz et al., 1999a), as well as poor reproductive performance (De Vries et al., 2010; Schneider et al., 2007), are known risk factors for culling in dairy cows. Among these risk factors, one of the most influential is clinical mastitis (CM; Gröhn et al., 1998; Rajala-Schultz et al., 1999c; Schneider et al., 2007); with the risk between mastitis and culling being time-dependent (Gröhn et al., 1997, 1998).

However, the culling decision could be based either on the disease status of the cow or on its current milk yield, milk production being a significant confounder when modelling dairy cow culling risk. High producing cows are at greater risk of mastitis (Barnouin et al., 2005; O'Reilly et al., 2006; Schukken et al., 1991; Waage et al., 1998), and a lower milk production compared to herd mates has a significant effect on culling decisions (Beaudeau et al., 1994; Hadley et al., 2006; Rajala-Schultz et al., 1999c). Moreover, cows that had an episode of CM are at greater risk for occurrence of other CM episodes later during their lactation (Lam et al., 1997; Zadoks et al., 2001). Similarly, a high somatic cell count (SCC) is a risk factor for mastitis as well as for culling (Caraviello et al., 2005; Sewalem et al., 2006; Steeneveld et al., 2008). The correct estimation of the effect of mastitis on culling requires the inclusion of milk yield (and SCC) in the modelling strategy. However, milk yield and SCC are time-dependent (or time-varying) confounders, which are also affected by prior CM (Rajala-Schultz et al., 1999d; Seegers et al., 2003), i.e. intermediate covariates. Therefore these covariates lie on the causal pathway between the exposure of interest, CM, and the outcome, while at the same time being risk factors for culling, as depicted in the directed acyclic graph (DAG) in Figure 6.1. Adjusting for variables that are confounders but also affected by prior exposure gives biased estimates of the true or 'causal' total effect. Failing to adjust for milk production and SCC would result in a biased effect estimate, yet adjustment for those variables would also result in biased estimates (Cole et al., 2010; Hernán et al., 2004). This methodological problem has been well described by Robins et al., 2000, Hernán et al., 2004, and Cole et al., 2008.

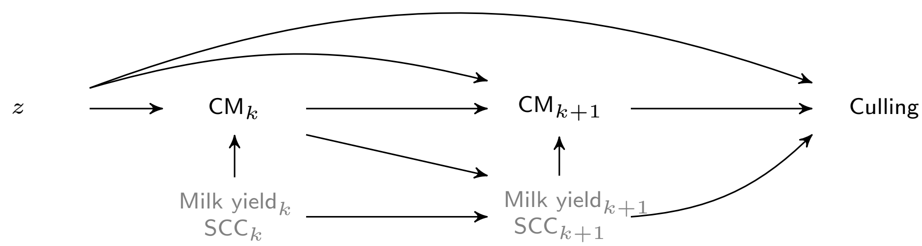

Figure 6.1 – Directed acyclic graph (DAG) for the effect of clinical mastitis on culling, with time points k. z is a vector of baseline covariates. CM, clinical mastitis; SCC, somatic cell count.

Marginal structural Cox models (MSM) provide the marginal causal relation between a time-varying exposure and a survival outcome (e.g. time to culling), controlling for time-varying confounders without conditioning on those variables (Cole et al., 2008; Hernán et al., 2000; Robins et al., 2000). The regression model relates the exposure history up to time t to the counterfactual outcome at time t. The model takes into account potential time-varying biases by creating weights for each subject at each time interval according to the inverse probability of the observed exposure and censored status of each subject. This weighting allows the construction, for a risk set at time t, of a 'pseudo-population' in which the time-varying confounders no longer predict CM at t, i.e. are no longer confounders, and the causal association between CM and culling is the same as in the original population (Hernán et al., 2000). Therefore the estimation of the unconfounded association between the exposure and outcome is now allowed without conditioning on the covariate in the regression model (Robins et al., 2000).

The issue of the direct and indirect effects of milk yield on culling risk due to mastitis was already raised by Gröhn et al. (1997; 1998). But biases due to time-varying confounders were not identified at that time and have not yet been properly addressed. The objective of this paper is to estimate the causal effect on culling of the time-dependent exposure CM, occurring between calving and 120 days in milk (DIM), by using a marginal structural model (Robins, 1999; Robins et al., 2000) to control for such time-varying confounders affected by previous exposure.

6.2 Materials and methods

6.2.1 Dataset

A retrospective longitudinal study was conducted on data from dairy herds in the Province of Québec, Canada, by extracting health information events from *DSA Laitier* (DSAHR Inc., Saint-Hyacinthe, QC, Canada), the dairy herd health management software used by more than half of Québec's producers and their veterinarians. We had access to a suitable sample of all lactations taking place between January 1st, 2001 and December 31st, 2010 (249,536 cows from 3735 herds), keeping herds that had a minimum of three consecutive years of follow-up with *DSA Laitier* and for which at least one culling was recorded over this follow-up. From this dataset, we extracted data for all lactations starting between January 1st and December 31st, 2010. If a cow had more than two lactations during the year 2010, only the first one was kept. Production data were obtained from the unique Québec dairy herd improvement (DHI) service provider (Valacta, Sainte-Anne-de-Bellevue, QC, Canada). Health and production data were matched based on herd- and cow-level identification. If not successful, further matching was tried, based on birth date, calving dates, and health and production history. Only herds for which at least 95% of the lactations from the health dataset could be matched with data from the production dataset were kept (42,809 cows from 714 herds). Herds with less than 30 animals, for which more than 30% of the DHI monthly tests were missing, and with a lactational cumulative incidence for CM in 2010 that was less than 15%, were removed. Cows with calving intervals, or an interval between the last calving and the end of data, longer than 580 days were censored at their last calving date.

If this censoring was at their first calving date, the observation was dropped. Cows leaving their herd on their calving date were assigned one day of follow-up.

The primary outcome, culling, was defined as a cow's being removed from the herd, i.e. due to death, sold to an other herd, or sent for slaughter. A new CM case was considered after a period of 7 days following a preceding CM case for that cow. Using data from *DSA Laitier*, we ascertained the exposure status (CM) for every primiparous and multiparous cow in terms of binary indicators in each monthly interval defined by the DHI monthly test, up to 120 DIM. The following potential baseline confounders were available for analysis: parity (1, 2, 3, 4+), calving season (January to July and August to December), age at first calving, pregnancy status, and occurrence of the following diseases: displaced abomasum, milk fever, and retained placenta. For multiparous cows, the following covariates were also retrieved from the previous lactation: occurrence of any CM case, real 305-day milk production, and 305-day SCC geometric mean. These last two covariates were standardized (z-score) for each parity strata (primiparous, parities 2, 3, and 4+) within each herd, and then categorized as 4 strata: average (-1 SD $<$ variable $<$ 1 SD; reference), low ($\leq$ -1 SD), high ($\geq$ 1 SD), and missing. The time-varying confounders monthly milk production and SCC were also standardized by test, parity, and herd, and the same categories as above were created. Missing values were given their own specific categorical level as a cow missing a test might be at a very high risk of culling and this information should not be discarded.

A CM variable was defined based on udder observations made by either the dairy producer or the farm veterinarian in which abnormalities of the udder and/or secretion were readily observable. Severity can vary but went from changes in milk, such as flakes, clots, and watery appearance, to acute mastitis, with a sudden onset, redness, swelling, hardness, pain, grossly abnormal milk, and reduced milk yield.

6.2.2 Data Analysis

Age at first calving was missing for 8.6% of the cows (parity 2 and over). The missing values were imputed using multivariate imputation by chained equation with the R package MICE (Van Buuren et al., 2011).

Two time-varying confounders (monthly SCC and milk production) were confirmed acting as confounders and mediators, i.e. that they were longitudinally associated with later CM case, were predicted by CM, and were associated with culling independently of CM. Then we conducted two separate sets of analyses for primiparous and multiparous cows. First, time-varying confounders were not included and only CM was considered time-varying at the monthly intervals defined by the DHI monthly tests. Both the exposure and the covariates were assumed to be constant during these intervals. The crude and adjusted risks of culling associated with CM were estimated using Cox proportional hazards models, stratified by herd. Herd effects could have been included as fixed or random effects. As the aim is to define a marginal, population average effect, stratification was chosen over random effects (Duchateau et al., 2008; Joffe et al., 2004).

Second, time-varying confounders were added to the framework of the MSMs. Marginal structural models are constructed as a two-step modelling strategy. First, the inverse probability of the treatment/exposure weights (IPTWs) were used to create a weighted sample in which the exposure is unconfounded by covariates (Cole et al., 2008). The IPTWs are the inverse of the probability of being exposed at each monthly test. Stabilized exposure weights $sw_i(t)$ and censoring weights $(sw_i^\dagger(t))$ were calculated using the method described by Hernán et al. (2000). IPTW at each time t was defined as,

$$sw_i(t) = \prod_{k=0}^{t} \frac{Pr\Big(A(k)|\bar{A}(k-1) = \bar{a}_i(k-1), V = v_i\Big)}{Pr\Big(Ak = a_i(k)|\bar{A}(k-1) = \bar{a}_i(k-1), \bar{L}(k) = \bar{l}_i(k)\Big)} \tag{6.1}$$

where the numerator and denominator represent the probability of CM $(A(k))$ for each cow i at each monthly interval $k(A(k) = a_i(k))$ given previous CM, $\bar{A}(k-1)$ without and also with conditioning on time-varying covariates $(\bar{L}(k))$, with V a vector of time-independent covariates, included in $L(0)$, respectively. Inverse probability of censoring weights were estimated the same way, except that the numerator and denominator represent the probability of remaining uncensored $(C(k))$ up to time t given past mastitis status, $\bar{A}(k-1)$ without and with conditioning on time-varying covariates, $\bar{L}(k)$, respectively:

$$sw_i^{\dagger}(t) = \prod_{k=0}^{t} \frac{Pr\Big(C(k) = 0|\bar{C}(k-1) = 0, \bar{A}(k-1) = \bar{a}_i(k-1), V = v_i\Big)}{Pr\Big(C(k) = 0|\bar{C}(k-1) = 0|\bar{A}(k-1) = \bar{a}_i(k-1), \bar{L}(k-1) = \bar{l}_i(k-1)\Big)} \tag{6.2}$$

Separate logistic regression models with herd as a random effect were fitted to determine probabilities for the numerators and denominators. The weights were stabilized in order to reduce their variability and the standard errors of the estimated hazard ratios (Cole et al., 2008). They were also trimmed at the 1st and 99th percentiles. The exposure and censoring weights were then multiplied to get the overall weights in each one-month interval, $sw_i(t) \times sw_i^{\dagger}(t)$. For the second step, Cox proportional hazards models were fit using these weights, stratified by herd and with a robust variance estimator, and estimating an average effect of CM over the follow-up period. Baseline covariates were included in these models, since the stabilization of the weights create a pseudo-population where there might still be residual confounding (Cole et al., 2008).

Marginal structural models are not subject to collider-stratification bias (Greenland, 2003), since the confounding effect of time-dependent confounders that are affected by prior mastitis status is controlled by weighting instead of conditioning. In all analytic methods, we assumed exchangeability (i.e. no unobserved confounding or non-informative censoring), consistency (a cow's potential outcome under her observed mastitis history is precisely her observed outcome), positivity (i.e. at every level of the confounders, cows in the population have a nonzero probability of experiencing every level of exposure, which implies that the average causal effect of mastitis can be estimated in each subset of the population defined by the confounders), and correct model specification.

All statistical analyses were performed with R version 3.3.2 (R Core Team, 2015).

6.3 Results

Table 6.I presents the characteristics of the 2999 primiparous cows and 6455 multiparous cows ($N = 9454$; 191 herds) that met the inclusion criteria. A total of 25.2% animals were culled during a mean follow-up time of 288 days (20.3%—306 days and 27.5%—280 days for heifers and cows, respectively). The herd size ranged from 30 to 205 cows (median: 53). More than 95% of the cows were Holsteins. Between calving and 120 DIM, 16.5% of the primiparous and 19.1% of the multiparous cows had at least one episode of clinical mastitis. Of the culled primiparous and multiparous cows, respectively 21.4% and 22.2% had at least one CM episode, compared to 15.3% and 17.9% for cows that were not culled. The median time between the first and second CM episode was 21 days (interquartile range: 14–45) for primiparous and 27 days (14–55) for multiparous cows. The intervals between the second and third cases were 22 days (12–33) and 19 days (13–30). Over 90% of culled animals were not pregnant compared to less than 20% of cows remaining in the herd (censored observations). Culled animals also produced less milk in their current lactation.

Table 6.II shows the crude and adjusted hazard ratios (HRs) with their 95% confidence intervals (CI) for culling associated with CM, when adjustment was made for baseline covariates. The crude, unadjusted HR suggests an increased culling risk from CM (HR = 1.80 [1.37–2.37] and HR = 2.10 [1.81–2.44] for primiparous and multiparous cows, respectively). The HRs adjusting for baseline characteristics (CM in previous lactation, parity, pregnancy, previous milk production, SCC ranking, dystocia, retained placenta, age at first calving, calving season) using a standard time-dependent Cox model were 1.54 [1.16–2.04] and 1.87 [1.58–2.20] for primiparous and multiparous cows, respectively.

Table 6.III shows the results of MSMs using the monthly interval approach. The stabilized IPTWs used in the marginal structural models have a mean of 0.99 for primiparous and 1.00 for multiparous cows (standard deviation of 0.05 and 0.09 for primiparous and multiparous, respectively). They ranged from 0.55

Table 6.I – Characteristics of primiparous and multiparous cows by culling status (n = 9454; 2999 primiparous, 6455 multiparous).

	Primiparous		Multiparous	
	Censored $N = 2391$	Culled $N = 608$	Censored $N = 4682$	Culled $N = 1773$
Parity				
2			1820 (39%)	459 (26%)
3			1236 (26%)	407 (23%)
4+			1626 (35%)	907 (51%)
Age at first calving (months)				
$>$ 24	342 (14%)	84 (14%)	663 (15%)	235 (15%)
24–26	1043 (44%)	255 (42%)	1834 (42%)	623 (40%)
26–28	581 (24%)	166 (27%)	1033 (24%)	403 (26%)
$>$ 28	425 (18%)	103 (17%)	812 (19%)	300 (19%)
Pregnancy				
Not pregnant	246 (10%)	559 (92%)	899 (19%)	1608 (91%)
Before 90 DIM	848 (35%)	20 (3%)	1311 (28%)	65 (4%)
90–120 DIM	391 (16%)	12 (2%)	656 (14%)	30 (2%)
$>$ 120 DIM	906 (38%)	17 (3%)	1816 (39%)	70 (4%)
Mean 305-day milk production[1], kg (SD)	8470(±1416)	7058(±2149)	10240(±1827)	9806(±1812)
Calved between August and December	831 (35%)	222 (37%)	1669 (36%)	675 (38%)
Milk fever	1 (0%)	2 (0%)	234 (5%)	181 (10%)
Displaced abomasum	83 (3%)	26 (4%)	170 (4%)	90 (5%)
Dystocia	276 (12%)	104 (17%)	337 (7%)	171 (10%)
Retained placenta	125 (5%)	35 (6%)	392 (8%)	177 (10%)
Metritis	86 (4%)	8 (1%)	214 (5%)	55 (3%)
Clinical mastitis in previous lactation			1014 (22%)	491 (28%)
Clinical mastitis during follow-up				
None	2025 (85%)	478 (79%)	3843 (82%)	1380 (78%)
One case	326 (14%)	108 (18%)	713 (15%)	320 (18%)
Two cases	29 (1%)	19 (3%)	94 (2%)	49 (3%)
Three cases	11 (0%)	3 (0%)	32 (1%)	24 (1%)
First mastitis case, mean DIM (SD)	21(±31)	13(±22)	33(±36)	26(±34)
Second mastitis case, mean DIM (SD)	66(±33)	36(±24)	60(±31)	53(±31)
Third mastitis case, mean DIM (SD)	75(±29)	41(±21)	80(±24)	73(±23)

[1]Based on real production; DIM = days in milk; SCC = somatic cell count; SD = standard deviation

Table 6.II – Estimates of association between clinical mastitis and culling obtained using different analytical approaches.

Models	Primiparous		Multiparous	
	HR	95% CI	HR	95% CI
Crude (not adjusted)	1.80	1.37, 2.37	2.10	1.81, 2.44
Adjusted for baseline covariates[a]	1.54	1.16, 2.04	1.87	1.58, 2.2
Marginal Structural Cox Model[b]	1.45	1.09, 1.92	1.49	1.26, 1.76

CI, confidence interval; HR, hazard ratio, SCC, somatic cell count.

[a] Baseline covariates: dystocia, retained placenta, age at first calving, and calving season for heifers; the same plus parity, clinical mastitis in previous lactation, milk production during previous lactation, and SCC ranking for previous lactation for cows.

[b] With stabilized exposure and censoring weights. Also adjusted for baseline covariates.

to 1.12 for primiparous and from 0.49 to 1.58 for multiparous cows, respectively. The estimated average CM causal HRs over time were 1.45 [1.09–1.92] and 1.49 [1.26–1.76] for primiparous and multiparous cows, respectively. Other effects on culling were still present after controlling for the time-varying confounders. Dystocia was a risk factor for both primiparous and multiparous cows. Multiparous cows showed additional risk factors from increasing parity and milk fever. Their past history also provided information on their culling risk. Having already experienced a CM during the previous lactation increased their culling risk by 14% (HR = 1.14 [1.02–1.27]). Multiparous cows for which milk production was below the average of their herdmates, in respect to their parity, had a HR of 1.21 [1.06–1.37]. On the other hand, above average milk production was a protective factor for culling (HR = 0.83 [0.71–0.96]). The SCC over their previous lactation was also a risk factor in reference to the herd/parity average value, from a HR of 1.41 [1.23–1.60] for above average cows and 1.41 for below average cows [0.94–2.12] to 1.60 [1.17–2.20] when the count was not available.

6.4 Discussion

Using data from a retrospective cohort study we demonstrated an increased causal risk of culling due to CM. This risk was of the same magnitude for primiparous and multiparous cows, and reduced compared to models not controlling for the

Table 6.III – Estimates of association between clinical mastitis and culling using Marginal Structural Cox Models.

Adjusted for	Primiparous		Multiparous	
	HR[a]	95% CI	HR[a]	95% CI
Clinical mastitis	1.45	1.09, 1.92	1.49	1.26, 1.76
Clinical mastitis in previous lactation			1.14	1.02, 1.27
Parity				
3 vs 2			1.14	0.99, 1.3
4+ vs 2			1.60	1.42, 1.8
Milk production during previous lactation				
Below average (vs avg)			1.21	1.06, 1.37
Above average (vs avg)			0.83	0.71, 0.96
Not available (vs avg)			1.26	0.87, 1.82
SCC ranking for previous lactation				
Below average (vs avg)			1.41	0.94, 2.12
Above average (vs avg)			1.41	1.23, 1.6
Not available (vs avg)			1.60	1.17, 2.2
Pregnancy	0.07	0.05, 0.1	0.10	0.08, 0.12
Dystocia	1.42	1.13, 1.8	1.27	1.08, 1.5
Displaced abomasum	1.02	0.68, 1.53	0.97	0.78, 1.21
Milk fever			1.69	1.42, 2.02
Retained placenta	1.15	0.82, 1.62	1.01	0.86, 1.19
Age at first calving				
24–26 months (vs < 24)	0.87	0.67, 1.14	0.92	0.79, 1.07
26–28 months (vs < 24)	0.90	0.68, 1.2	1.00	0.84, 1.18
>28 months (vs < 24)	0.80	0.58, 1.11	0.95	0.79, 1.13
Calving between August and December	0.97	0.81, 1.16	0.97	0.88, 1.07

CI, confidence interval; DIM, days in milk; HR, hazard ratio; SCC, somatic cell count.

[a] Estimated from a marginal structural Cox model, adjusted for baseline covariates.

time-varying confounders milk yield and SCC. However the estimates were large, potentially implying that an indirect effect of mastitis on culling through reduced milk yield and higher SCC is not the only process at play in the culling process. Our study is also the first to deal with the biases associated with the presence of time-dependent confounders, adding to the literature on dairy cow culling risk.

Compared with estimates from the standard adjusted model, estimates from the MSMs were 19% lower for primiparous and 29% lower for multiparous cows. Adjustment for milk yield and SCC was more pronounced in multiparous than primiparous cows, suggesting that the culling decision based on these factors was less stringent for heifers than for cows. Hazard ratios reported previously in the literature for models including milk production and SCC or both as covariates ranged from 1.6 to greater than 2. Some of these results were from random effect models (Caraviello et al., 2005; Schneider et al., 2007), i.e. population-average estimates which give larger estimates. Other studies by Gröhn et al. (1997) and Rajala-Schultz et al. (1999c) modelled milk production as a time-dependent covariate. However none of these studies addressed the bias introduced by including a time-dependent confounder in the model. In observational studies we have to adjust for confounders to properly estimate the influence of the factor of interest on the outcome. In the presence of time-dependent confounders that are affected by prior exposure and that are therefore on the causal pathway, their control as in a conventional time-dependent Cox model is not appropriate, as this results in conditioning on common effects (Cole et al., 2010; Hernán et al., 2004). By using IPTW in the MSM, a pseudo-population is created where at each time point the probability of exposure is no longer associated with the measured potential confounders. The resulting estimates represent the total effect of CM including intervening pathways through milk yield and SCC.

The effect of the fixed-time confounding variables were on par with what is found in the literature (Beaudeau et al., 1994; Gröhn et al., 1998; Rajala-Schultz et al., 1999b). Lower producing cows have already been reported as being more at risk for culling (Beaudeau et al., 1995; Gröhn et al., 1998; Schneider et al., 2007). The effect of the cow's SCC characteristics from previous lactation was also related to previous studies. Somatic cell count is an important risk factor for CM (Beaudeau et al., 1998; Green et al., 2004; Suriyasathaporn et al., 2000). It has also been shown that high SCC herds have a higher culling rate and that culling occurs earlier in lactation (Caraviello et al., 2005). Moreover, cows having a high SCC for their lactation were probably chronically infected, which could increase the bulk tank SCC (Madouasse et al., 2010). Their removal from the herd is therefore a good strategy for the dairy producer to manage his/her bulk tank SCC regulatory limit. In this study, cows with lower current lactation SCC compared to herd mates had a higher culling risk as well (HR = 1.41), even if the confidence interval is wide, and barely including 1.0.

Marginal structural models have several key assumptions that must be satisfied: exchangeability, consistency, positivity, and correct model specification (Cole et al., 2008). The exchangeability assumption, or no unmeasured confounding, also includes that there should be no informative censoring due to unmeasured covariates. Sensitivity analyses to evaluate unmeasured confounders were developed for linear-, Poisson-, and logistic-MSMs (Brumback et al., 2004). In a survival analysis with Cox regression, Klungsøyr et al. (2009) developed a sensitivity analysis for a point exposure design (constant exposure or single assessment). However no sensitivity analyses are readily available for repeated exposures in a Cox survival model. The exchangeability assumption cannot be verified empirically and we assumed therefore that the measured covariates included in the analysis were sufficient to control for confounding bias. Consistency, i.e. that the observed outcome for each cow should be the causal outcome resulting from each cow's set of observed risk factors, is also difficult to verify. Positivity requires that there are exposed and non-exposed subjects at every level of the confounders. Clinical mastitis cases occur most often early in lactation (Barkema et al., 1998; Olde Riekerink et al., 2008; Sargeant et al., 1998). By focusing on the lactation period between calving and 120 DIM, we excluded periods of zero exposure probability from the data set, meeting the positivity requirement. The positivity assumption also applies to the presence of clusters in the analysis, here the various herds. All herds selected for analysis had at least one case of CM, therefore meeting the positivity assumption. Correct model specification implies that appropriate functional forms are used in the logistic models used to determine the weights, and in the final weighted model. While positivity and correct model specification are mainly working assumptions, they can be further confirmed by the absence of extreme weights and by having a mean weight close to 1 (Cole et al., 2008; Howe et al., 2011).

Finally, the analysis is based on the assumption of random measurement error. Using a retrospective, observational data set following a user-defined event recording scheme, both the exposure and the outcome are at risk of measurement errors that are correlated with each other, potentially leading to differential misclassification of culling by CM status. We tried to overcome this issue by selecting herds with a comprehensive record of health events. But we still lack precision on CM as no information on its severity was available, and dairy producers might be more likely to report the most severe cases. We have, however, good confidence on the reporting of culling, veterinary-treated and veterinary-supervised conditions, as well as pregnancy status. Likewise, we restricted the analysis to herds with satisfactory matches between health and production record data sets, to improve our confidence in the milk production information.

6.5 Conclusion

Our findings confirm that CM is a risk factor for culling, but with reduced effect compared to previous studies, which did not properly control for time-dependent confounders. Heifers and cows also experienced the same risk for CM, milk production having less influence on the culling decision in heifers than cows. However, after controlling for the potential confounders, the culling risk was still large and other factors might influence the culling decision process. Unmeasured confounders require further evaluation through sensitivity analyses to be developed in the framework of time-varying exposure.

Conflict of interest

None.

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CHAPITRE 7

CULLING FROM THE ACTORS' PERSPECTIVES—DECISION-MAKING CRITERIA FOR CULLING IN QUÉBEC DAIRY HERDS ENROLLED IN A VETERINARY PREVENTIVE MEDICINE PROGRAM

Denis Haine[1], Roger Cue[2], Asheber Sewalem[3], Kevin Wade[2], René Lacroix[4], Daniel Lefebvre[4], Jonathan Rushton[5], Julie Arsenault[1], Émile Bouchard[1], Jocelyn Dubuc[1]

[1]Faculté de médecine vétérinaire, Université de Montréal, 3200 rue Sicotte, C.P.5000, St-Hyacinthe, Québec, Canada J2S 7C6

[2]Department of Animal Science, McGill University, 21 111 Lakeshore Road, Ste-Anne-de-Bellevue, Québec, Canada H9X 3V9

[3]Guelph Food Research Centre, Agriculture and Agri-Food Canada, 93 Stone Road West, Guelph, Ontario, Canada N1G 5C9

[4]Valacta Inc., 555 boul. des Anciens-Combattants, Ste-Anne-de-Bellevue, Québec, Canada H9X 3R4

[5]The Royal Veterinary College, University of London, Hawkshead Lane, North Mimms, Hatfield, Hertfordshire AL9 7TA, United Kingdom

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Contributions

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D. Haine	X	X	X		X	X
H. Delgado		X				X
R. Cue	X					X
A. Sewalem	X					X
K. Wade	X					X
R. Lacroix		X				X
D. Lefebvre		X				X
J. Rushton			X			X
J. Arsenault			X	X	X	X
É. Bouchard	X					X
J. Dubuc	X		X	X	X	X

Abstract

The series of events leading to the decision to cull a cow is complex, involving both individual-level and herd-level factors. While the decision is guided by financial returns, it is also influenced by social and psychological factors. Research studies on the motivational and behavioural aspects of farmers' decision utility are sparse, and nonexistent regarding culling expectations and its decision process. Our goal was to identify shared criteria on culling decisions held by dairy producers and farm advisers, with the help of the Q-methodology.

Forty-one dairy producers and 42 advisers (17 veterinarians, 13 feed mill advisers, and 12 dairy herd improvement (DHI) advisers) undertook a Q-sort with 40 statements that represented a range of views about cow and herd health, production performance, management issues, and material factors that might impact their culling decision-making process. The sorts were analysed by-person using factor analysis and oblimin rotation.

A single view on culling could be identified among dairy producers that can be extended to dairy farm advisers, who showed two variations of the same well-structured, uni-dimensional decision-making process. Udder health, milk production performance, and milk quota management were the key criteria for the culling decision. Farm management parameters (debts, amortization, employees, milking parlour capacity, herd size) did not play any role in the decision process. Three key differences were, however, identified between producers and the two types of advisers. One group of advisers followed the recommendations from mathematical models, where pregnancy is a major determinant of a cow's value. They assessed the cow in a more abstract way than did the other participants, still taking into account udder health and milk production, but adding economic considerations, like the availability of financial incentives and an evaluation of the post-partum health of the cow. Dairy producers were also more concerned about producing healthy and safe milk, which might reflect a different value given to dairy farming than by advisers. Very different degrees of importance were given to animal welfare by the three groups, which could represent different views on the attributed relationships between dairy farmers and their animals.

Our findings suggest that dairy producers and their advisers hold a general common view regarding culling decision-making. However there are significant differences between producers and advisers, and among advisers. Understanding and managing these differences is important for assisting the change management processes required to increase farm profitability, and call for further investigation.

Keywords culling, dairy cow, Q methodology, Qualitative research.

7.1 Introduction

The process leading to the decision to cull a cow is complex, involving both individual-level (milk production level, stage of lactation, reproductive status, age, genetic value, health problems) and herd-level factors (herd short and long-term dynamics, production needs, availability of replacement animals, price of milk and culled cows, milk quota; Dohoo et al., 1993). The cost associated with animal replacement is substantial, second in importance only to feeding costs and labour. As such, the decision to cull a cow is a farm management decision for the dairy producer to better reach his goals. While minimizing the total losses (the sum of the production loss and disease control expenditures) is recognized to be the most profitable approach (McInerney et al., 1992), dairy producers have flexibility regarding the timing of their decisions and have to deal with certain constraints (e.g., regulations, quotas, etc; Wallace et al., 2002). Bigras-Poulin et al. (1985) already demonstrated that a farmer's socio-psychological characteristics were more important to farm performance than herd-level variables describing production, health, and fertility. These results were later confirmed by other studies (Bergevoet et al., 2004; Willock et al., 1999). Farmers' decisions are certainly guided by financial returns, but are also influenced by social and psychological factors (Beaudeau et al., 1996; Edwards-Jones, 2006). Their behavioural choices are constrained and facilitated by their social context. Holding a complex set of core values makes some choices more appealing than others even if they might not be as financially rewarding (Garforth, 2010).

To help them make decisions on their farm operations, dairy producers can have access to several resources, including veterinarians, consultants, industry representatives, and Dairy Herd Improvement (DHI) personnel (Jensen et al., 2009; Jordan et al., 1993). Over the years, veterinary practitioners have seen their role and responsibilities moving from diagnosing and treating clinical diseases on individual animals, to an integrated approach to disease prevention and herd health improvement, leading to a rise in herd productivity (LeBlanc et al., 2006; Mee, 2007). By doing so, they had to acquire skills in nutrition, cow/calf housing, data analysis, fertility management, milk quality, economics, and farm guidance. Their role evolved from mostly clinical, task-oriented, service providers to one of advice-oriented consultants (LeBlanc et al., 2006). Following this change in role, they had to engage with other specialists already present on the farms, like nutritionists, lenders, milk processors, extension educators, etc. Advisory teams including all these players could even be built to support farmers in the implementation of 'best practice' farm management (Chase et al., 2006; Noordhuizen et al., 2007).

In classic economic theory, it is assumed that people make decisions based on the expected changes in their 'well being', referred to as 'utility', searching for a maximum utility level (Edwards-Jones, 2006). Likewise, agricultural economic models assume that farmers maximize utility and, as utility is hard to measure, profit is used as a surrogate for utility (Wallace et al., 2002). However, profit maximization is only one of many motivations determining decision-making behaviour. For any given choice, people have to use some implicit decision rules based on their goals and motivations. These decision rules do not have to translate the 'maximization of something', or even to maximize anything at all (Edwards-Jones, 2006; Wallace et al., 2002). Even if researchers can model this maximization post hoc, people might not have psychologically followed that process (Ahuvia, 2008). Based on criteria that have varying degrees of explicitness, the decision maker will prefer one course of action over others. We can define decision utility as the utility that determines our choices (Kahneman et al., 2006; Robson et al., 2011). Decision utility is what people maximize when making choices (Robbins, 1935; Samuelson, 1938). Making a decision involves freedom of choice, even if these choices could be constrained. And the choices made reveal preferences, i.e. subjective judgments about (1) the relative importance of the collected facts, (2) personal values, (3) the requirements for implementing the course of action, and (4) the relative significance of these judgments (Stephenson, 1973).

A prevailing behavioural aspect of decision making is loss aversion or *status quo* bias (Samuelson et al., 1988). When making a decision about gains, individuals are risk averse, whereas they are risk loving when they have to make a decision about losses (Kahneman et al., 1979), i.e. losses from a reference state are valued far more negatively than the positive value obtained from gains, and less risky, but lower, gains are preferred to higher, uncertain, gains. Farmers in general (Bocquého et al., 2014), and dairy farmers specifically (Huijps et al., 2010), have been demonstrated to follow this loss aversion behaviour. However, one group of people has been shown not to adhere to this behaviour, manifesting a less loss-averse set of actions. Advisers are recognized to more heavily weight the advantages of a decision than its disadvantages (Lu et al., 2014; Polman, 2012).

Producers and advisers can rely on decision support systems (DSS) to enhance their culling decision process. These DSS estimate a cow's economic value based on mathematical models (Cabrera, 2010; De Vries, 2006a; Kalantari et al., 2010). However, these models can become very large and complex (Demeter et al., 2011). Due to these complexities, few of them have found a practical application in daily decision-making by milk producers or even been translated into a user-friendly decision support system (Groenendaal et al., 2004; Smith et al., 1993). In all of these models, the importance of pregnancy is critical for the determination of a cow's value, and hence the decision to keep or replace the cow (Cabrera, 2012; De Vries, 2006a; Kalantari et al., 2010; Nielsen et al., 2010).

While the choices made by dairy producers are likely rational, they are also bounded by personal values and the limits of human cognition, potentially falling back on the use of short cuts and rules of thumb. The culling decision is therefore complex, context related, exists within constraints, and is possibly influenced by individual differences. These differences and the rationales behind the decision are important for understanding the choices made and for facilitating communication between actors at the farm. Research studies on the motivational and behavioural aspects of farmers' decision utility are sparse, and nonexistent regarding culling expectations and the culling decision process. Therefore, in the current study, we have sought to identify shared criteria for the culling decision, held by dairy producers and farm advisers, using the Q methodology.

7.2 Materials and methods

7.2.1 Overview of the Q Methodology

The Q methodology was first described by Stephenson (1935a,b), combining quantitative research techniques and analysis with qualitative approaches to pattern interpretation (Brown, 1980; McKeown et al., 2013; Watts et al., 2012). The Q methodology provides a means to identify the various preferences of each decision maker and their relative influence on the decision, revealing the decision structure of each individual (Durning et al., 2006). It allows researchers to identify groups of participants with similar viewpoints, by determining different patterns of thought rather than their numerical distribution among a larger population. The focus is not on the estimation of the proportions of participants (here, the dairy producers and the advisers) holding a specific view on a topic, but to identify qualitative categories of views shared by these groups of participants. This methodology has been effectively applied to various areas of research, including many issues of human health, like clinical decision making (Wong et al., 2004) or educational programs (Wallenburg et al., 2010), and sometimes encountered in veterinary medicine or animal health studies (de Graaf, 2005, 2007; Kristensen et al., 2008, 2011).

In a Q methodology study, the participants rank a set of statements, the 'Q-set', sorting them according to a subjective dimension, such as 'agreement/disagreement' or 'most like me/least like me'. The sorting is referred to as the 'Q-sort'. By sorting these items, the participants reveal their viewpoints on the issue under study, i.e. the vantage point from which they understand and order the items. The Q-sorts of the different individuals are subject to correlation analysis. Clusters of correlations are then contrasted by factor analysis, revealing distinguishable viewpoints.

7.2.2 Q-Set Design

A 'Q-set' of statements of criteria used when evaluating a cow to be culled was developed for the participants to rank. A comprehensive list was first drafted, as far as was possible, of the criteria dairy producers and farm advisers could possibly take into account when they have to decide to cull a cow or not. For this, a review of both the scientific and non-scientific literature was carried out, as well as a scan of the technical and annual reports of the major North American DHI organizations and dairy producers' associations. Three researchers refined the initial sample of approximately 100 items to a Q-set made of 40 statements, by removing duplicates, double-barrelled propositions, and ambiguous statements, merging similar ones, etc. The Q-set was pilot tested by one dairy producer for clarity of instructions and statements, as well as any missing ones. The final Q-set is given in Table 7.I. All instructions and statements were written in French. While the producers received first-person account statements, the advisers got them as third-person. The statements were randomly allocated a number between 1 and 40 and printed onto cards.

7.2.3 Participants

One pack of materials (containing the Q-set, instructions, and response grid) was given to 60 dairy producers under the preventive medicine program of the ambulatory clinic, Faculté de médecine vétérinaire (FMV), Université de Montréal, QC, Canada, visited between February 1, 2014 and April 30, 2014. If a producer

Table 7.I – Q-set statements and idealized (weighted and normalized) Q-sorts within dairy producers and farm advisers' perspectives on culling. Participants received instructions and statements in French. Producers received first-person account statements; advisers got them as third-person.

id	Statement	Producers	F1 Advisers	F2 Advisers
1	I have to consider amortizing materials, buildings, mechanics	−4	−4	−4
2	Season of the year	−1	2	−2
3	I need room for replacement heifers	−1	1	−1
4	I think about herd/cow health first before cow longevity	0	−1	1
5	If pregnant	1	4	2
6	I have replacement heifers available	−1	0	0
7	I have to produce a healthy and secure milk	2	−2	2
8	Cow's somatic cell count	4	4	4
9	Her annual production	2	2	1
10	Her lactational stage	1	2	1
11	If she ever had difficulties calving	0	0	−1
12	Her body condition score	−1	−1	−1
13	Her daily production	2	2	2
14	Heifer price	−2	−1	−2
15	If she had diseases after calving (e.g. RP, metritis, MF)[1]	0	2	0
16	Milk price	−2	−3	−2
17	I had warnings for bulktank somatic cell count	3	3	4
18	Debts	−3	−2	−3
19	Herd genetics	−1	−2	−1
20	Her number of articial inseminations	2	3	1
21	Herd size	−2	−3	−3
22	Her conformation	1	0	0
23	Her projected production for the current lactation	1	1	1
24	Cow welfare	0	−2	2
25	I know which ones have chronic mastitis in the herd	4	1	3
26	Her gestational stage	0	1	−1
27	There's a market for my heifers	−3	−1	−2
28	Number of employees on the farm	−4	−4	−4
29	I can always buy cows in the market	−2	−1	−3
30	She ever had clinical mastitis	3	1	2
31	I'm over- or under-milk production	2	3	3
32	Her age	−1	0	−1
33	Withdraw period for milk or meat	0	−1	3
34	Milking parlour capacity	−3	−3	−2
35	Ease of milking	1	1	0
36	Culling rate	−2	−2	−1
37	Her udder conformation	1	0	1
38	Culled cow price	−1	0	0
39	She's got abnormal milk	3	1	1
40	Cow genetics	1	−1	0

[1] RP = retained placenta; MF = milk fever.

declined to participate, his pack was given to another one. The pack was retrieved on the following preventive medicine visit, and the producer was rewarded with a $25 gift card if the material was completed.

Veterinary practitioners doing preventive veterinary medicine were recruited at a continuing education course held at the FMV on January 2014 as well as through VETBOVIN-L [1], a Québec, francophone web discussion list for bovine practitioners. Thirteen veterinarians from Québec responded to our call, to which we added five veterinarians from the FMV ambulatory clinic.

Twelve advisers from Québec DHI were volunteers for the study. Dairy production advisers from three Québec feed mills were asked to participate. Two feed mills provided 8 advisers each, and 6 came from the third one.

7.2.4 Administration of the Q-Sort

All participants received the same guidance on the completion of the card sorting exercise. Dairy producers were asked the following question: 'Which among the following are the most and least influential criteria to decide to cull a cow in your herd?'. Advisers received the same question but asked as third-person ('in a herd'). Participants were asked to read carefully the 40 items and arrange them into three piles according to their judgment about the criteria they use when deciding to cull a cow: 'influential', 'neutral' and 'not influential'. Next, they were asked to sort them into a grid (Figure 7.1), the response matrix, ranging from -4 (not influential) through 0 (neutral) to $+4$ (very influential). Hence the two most influential items were placed under $+4$, followed by the three next influential with items in $+3$, and so on, until a quasi-normal distribution was produced. The cards were attached onto the matrix with Velcro tape, and collected at the next preventive medicine visit. Statements in each Q sort were coded according to their position in the response matrix, i.e. from -4 to $+4$.

1. `http://www.dsahr.ca/liens/VetBovin.aspx`

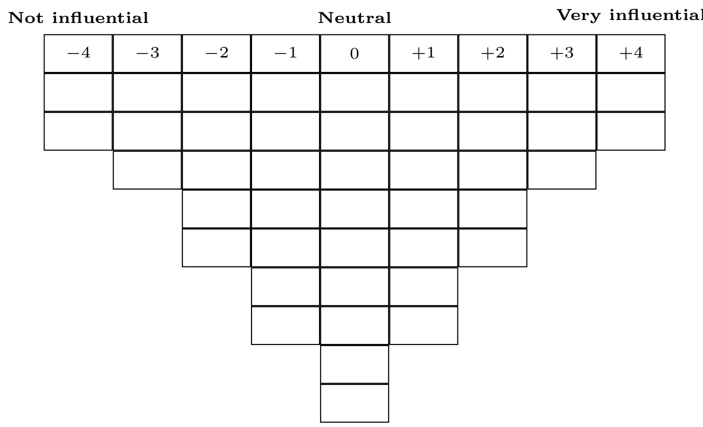

Figure 7.1 – Q sort response grid.

7.2.5 Statistical Analyses

The Q-sorts from the dairy producers on the one hand and farm advisers (veterinarians, DHI and feed mill advisers) on the other were analysed separately. The rationale for analysing the two groups, producers and advisers, separately was to be able to comprehend the views of both groups in their own right (Watts et al., 2012), which would not be allowed by mixing them together. Secondly the administration of the Q-sort was not exactly the same in the two groups, as one group, the producers, was asked about their own herd and cows, i.e. in the first person, and the second, the advisers, was asked about herd and animals they don't own, i.e. in the third person. This also leads to the third reason. As their decision making behaviour regarding loss aversion potentially gives these two groups different vantage points on the understanding of the questions, involvement in the decision process, and feedback on the decision outcome, mixing them together would have confused the interpretation of the results.

A correlation matrix was created, displaying how each participant's unique 40-statement rank-ordered Q-sort correlated with each of the other participants' unique 40-statement arrangement. Using the correlation matrix as raw data, groupings of Q-sorts in which participants placed statements in significantly similar fashions were determined. Each grouping of Q-sorts (i.e. a grouping of participants) represented a factor (a particular point of view). For each sample of participants (dairy producers, farm advisers), the factorability of the matrix was evaluated using Bartlett's Test of Sphericity (Bartlett, 1950). Then factor extractions were made by an exploratory factor analysis using the minimum residual (Harman et al., 1966). The number of factors to be extracted was investigated by a parallel analysis (Horn, 1965), employing the Very Simple Structure (VSS) criterion (Revelle et al., 1979), Velicer's Minimum Average Partial (MAP) test (Velicer, 1976), and the broken-stick distribution (Frontier, 1976). The factor structure was simplified using oblimin rotation (Harman, 1976). Significant factors were then extracted by applying the rule from Brown, 1980. Factor loadings, i.e. the correlations between each Q-sort and each factor, were obtained from the factor extraction. The loading expresses the extent to which each Q-sort is associated with each factor extracted. Brown, 1980 suggests that a significant factor loading at the 0.01 level is calculated using the equation $2.58 \times ({}^{1}/\sqrt{\text{no. of statements}})$. Here, this value was $2.58 \times ({}^{1}/\sqrt{40}) = 0.408$. For reliability, a factor is kept if it is the composite of at least three Q-sorts. Those Q-sorts significantly loading on the same factor share a similar sorting pattern. They are known as *exemplar sorts* in that they best exemplify the viewpoint represented by the factor.

The exemplar sorts are then merged to form a single ideal-typical Q-sort for each factor, called a *factor array*. The *factor array* is the normalized weighted average statement score of respondents that define that factor. The weight (w) is based on the respondent's factor loading (f) and is calculated as $w = {}^{f}/(1 - f^2)$. The weighted average statement score is then normalized (with a mean of 0.00 and SD = 1.00) to remove the effect of differences in the number of defining respondents per factor, thereby making the statements' factor scores comparable across factors. Then tentative factor labels were chosen as simple, short reminders of the composite viewpoint of the whole factor, reflecting the makeup of the factor.

The comparison between the two groups, dairy producers and advisers, was made post hoc. A second-order factor analysis was performed using the factors identified in the two groups of dairy producers and farm advisers. Our goal was to check whether the decision-making process of the participants were group-specific or based entirely or partially on a general core of shared principles. The composite *factor arrays* from the two original Q-sort analyses were factor analysed again, following the same method as above, and new factors identified.

All statistics were computed with R version 3.3.2 (R Core Team, 2015), `psych` package (Revelle, 2015)—parallel analysis with `paran` package (Dinno, 2012).

7.2.6 Ethics

Ethical approval for the study was obtained from Université de Montréal Ethics Committee (CERES; 14-016-CERES-D).

7.3 Results

A total of 41 producers and 43 advisers participated in the study. One feed mill adviser had missing statements in his Q-sort and was excluded from the factor analysis. The dairy producers had either secondary school/professional or college/technical education (44% and 51%, respectively; one had a university degree). The characteristics of the participating farms are summarized in Table 7.II. The median number of animals in lactation was 48 (lower and upper quartiles: 39 and 58, respectively). The farms got their revenue mainly from dairy, but not exclusively (median proportion of revenue from dairy: 75%; lower and upper quartiles: 65% and 90%, respectively). The sample of feed mill advisers was fairly well-educated (i.e. 64% had a university degree) and more experienced (i.e. median of 12 years) than the DHI advisers (education evenly spread between college/technical and university; median experience of 9 years). Most of the participating veterinarians (59%) spent at least 50% of their monthly working time in preventive medicine for dairy cattle.

After examination of the statistical characteristics of the factors, a two factor solution emerged both for the analysis of the dairy producers and for that of the advisers. The second factor for the dairy producers was defined by less than three non-confounded Q-sorts (i.e., one) and was therefore not retained for the interpretation. The factor loadings for the dairy producers and the advisers are shown in Tables 7.III and 7.IV respectively.

In the three subsections which follow, each factor is presented, using factor scores and distinguishing statements. In describing the factors, the first number within parentheses refers to the statement number, and the second number indicates its ranking.

7.3.1 Dairy Producers' Views I (F1)—Udder Health Focus

The single retained factor for dairy producers had an eigenvalue of 16.7 and explained 40.8% of the study variance. Thirty-five of the 41 producers were significantly associated with this factor.

Dairy producers evaluated first and foremost the udder health of the cow and herd, through the cow's somatic cell count (SCC; #8: +4), by knowing which cows in the herd have chronic mastitis (#25: +4), warnings received for bulktank SCC (#17: +3), the presence of abnormal milk (#39: +3), and if the cow ever had clinical mastitis (#30: +3). They are also engaged in having to produce healthy, safe milk (#7: +2). Then they look at production parameters: the cow's annual and daily production (#9: +2; #13: +2) and if the herd is over- or under-producing relative to quota (#31: +2). Difficulties getting the cow pregnant are also considered, according to the number of artificial insemination (AI) services she received (#20: +2). Other reproduction parameters were not very much taken into account (being pregnant—#5: +1; gestational stage—#26: 0). Farm parameters are not included in the decision process to cull a cow: number of employees on the farm (#28: −4), amortization of materials, buildings, mechanics (#1: −4), milking parlour capacity (#34: −3), farm debts (#18: −3), herd size (#21: −2). The culling rate is also a piece of information having very little weight in the decision-making process (#36: −2). Heifers (needing room for them—#3: −1; their availability—#6: −1) are also attributed a low influence in the decision, but could be considered modulators of the decision, as are genetics (cow—#40: +1; herd—#19: −1) and health problems after calving (#15: 0).

7.3.2 Advisers' Views I (F1)—Economic Focus

The advisers' factor representing an economic focus had an eigenvalue of 11.7 and explained 27.9% of the study variance. Twenty-one advisers were significantly associated with this factor, of which 8 were veterinarians (47% of the 17 vets), 8 were from a feed mill (62% of the feed mill advisers), and 5 from the DHI (42%). Sixty percent of the DHI and 62% of the feed mill advisers with this factor had received a university degree. The median experience of feed mill advisers was 27 years, while it was only 7 years for DHI advisers. The majority (63%) of the veterinarians associated with this factor spent less than 50% of their time doing preventive medicine.

Like the dairy producer profile, farm economics were not taken into account, as seen from the low score given to the amortization of materials, buildings, mechanics (#1: −4), the number of employees on the farm (#28: −4), herd size (#21: −3), milking parlour capacity (#34: −3), and farm debts (#18: −2). They also use the same key decision points: cow's SCC (#8: +4), cow's daily production (#13: +2), warnings for bulktank SCC (#17: +3), and being under- or over-production (#31: +3). But they give a greater importance to the reproduction parameters, i.e. the pregnancy status of the cow (#5: +4), the number of AI services received (#20: +3), and the cow's gestational stage (#26: +1). They modulate their decision according to the season of the year (#2: +2), whether room is needed in the barn for the coming heifers (#3: +1), and whether the cow had diseases after calving (#15: +2). In contrast, they give less importance than the other profiles to cow welfare (#24: −2), having to produce a healthy, secure milk (#7: −2), and the withdrawal period for milk or meat (#33: −1). They are also less likely to adjust their decision according to knowing which cows in the herd have chronic mastitis (#25: +1). They declare further that they give more thought to herd/cow health than to cow longevity in their decision making (#4: −1).

7.3.3 Advisers' Views II (F2)—Animal Welfare Focus

The factor representing an animal welfare focus had an eigenvalue of 8.1 and explained 19.2% of the study variance. Thirteen advisers were significantly associated with this factor (29% [5] of the veterinarians, 23% [3] of the feed mill advisers, and 42% [5] of the DHI advisers). The majority of the DHI and feed mill advisers associated with this factor had received a college/technical education (60% and 67% respectively). All veterinarians in this profile spent more than 50% of their time doing preventive medicine.

This profile uses the same key points as the other two regarding udder health and milk production. But they give more importance to cow welfare (#24: +2), the withdrawal period for milk/meat (#33: +3), and (vs. the other adviser profile) having to produce a healthy, secure milk (#7: +2). They also give more importance to knowing which cows in the herd have chronic mastitis (#25: +3). They do not pay attention to the season of the year (#2: −2), reproduction (pregnancy status—#5: +2; number of AI services—#20: +1; gestational stage—#26: −1), the presence of diseases after calving (#15: 0), or having the possibility of buying cows in the market (#29: −3).

7.3.4 Second-Order Factor Analysis

A second-order factor analysis was used to determine the common shared subjective dimensions, if any could be found, in the variety of perceptions. This second-order factor analysis began with the three views identified above as variates and ended with a highly correlated single-factor solution (an explained variance of 78.4%). Each original view had an estimated composite reliability (h^2, or communality) greater than 50% (98%, 58%, and 81%, respectively, for dairy producers, advisers' first factor, and the advisers' second factor).

7.4 Discussion

Q-methodology studies are exploratory, qualitative investigations relying on small, non-randomized samples of participants (i.e. typically 25 to 40 respondents) conducting a large number of 'tests' (i.e. ranking 30 to 50 statements). As a consequence, the results of a Q study can only be generalized to the subject area from which the statements were sampled, but not—as in survey research—to the population (Brown, 1980; Watts et al., 2012). Generalizations can be drawn about the nature of the opinions and shared perspectives that exist on a given topic; while the frequency of people and their characteristics associated with each viewpoint cannot be inferred (Thomas et al., 1992; Van Exel et al., 2005). The interest of the Q-methodology is in uncovering opinion clusters. These clusters can later be investigated with classical survey methods regarding their prevalence among the general population. Therefore, the results from this study are directly applicable to the particular participants, settings, and contexts, but inferences to the general population or other groups are to be made with care.

Our main finding is that there is one well-structured, uni-dimensional decision-making process across groups. The single view identified among the dairy producers can be extended to the dairy farm advisers, who showed two variations on the same framework. The output of the dairy enterprise is of prime importance in the decision process. Milk quality, udder health, planned production and quantity of milk produced are carefully considered before making the decision. On the other hand, farm economics, i.e. debts, number of employees, amortization of materials, buildings, and mechanics, milking parlour capacity, or herd size, do not play a role in the decision to cull a cow. Elements requiring a mix of data collection and analysis, with the interpretation of the results to the wider business, are thus not included in the decision, even though they can mediate farm profitability through its efficiency and productivity.

This decision framework is similar to risk factors or reported disposal codes for culling. Failure to conceive, mastitis, SCC, low milk yield, and age or parity are the major reported reasons why cows leave the herd (Bascom et al., 1998; Beaudeau et al., 1995; Rajala-Schultz et al., 1999c). While the most important risk factor for culling is reproduction status (Beaudeau et al., 1995; Pinedo et al., 2014; Rajala-Schultz et al., 1999b; Seegers et al., 1998), it was put forward only by 'Economic Focus' advisers. All statements related to reproduction were ranked higher by 'Economic Focus' advisers than in the other two factors, with pregnancy status and number of inseminations being determinant in their decision. Reproduction status is not the most influential parameter taken into account by producers (and 'Animal Welfare Focus' advisers), but is the culling reason they most often report. It can be assumed that the reliability of the reported culling reasons is questionable, as they are subjective (Stewart et al., 1977), and recall bias might be present. Even if udder health and cow's production are the top influential parameters, the number of inseminations is close. The beginning of lactation is at high risk for mastitis and milk production losses resulting from it (Dürr et al., 2008; Hagnestam-Nielsen et al., 2009; Rajala-Schultz et al., 1999d). Failure to conceive will come into play a few months later into lactation, may trigger the culling decision, and be the reason reported. But there is a set of factors which lead to that decision, of which reproduction is a secondary element according to producers. But that element might hold the balance of the decision.

Three key differences were identified between producers and the two types of advisers. 'Economic Focus' advisers were named as such because this profile, or factor, follows the recommendations from mathematical models, where pregnancy is a major determinant of the cow's value (Cabrera, 2012; De Vries, 2006a; Kalantari et al., 2010; Nielsen et al., 2010). These advisers appear to judge the cow in a more abstract way than do the other participants. While still considering udder health and milk production, they complement their evaluation by including additional economic considerations, like the season of the year, i.e. the availability of financial incentives, and post-partum diseases. The province of Québec (Canada) has a system of premiums for milk produced between August and November, i.e. extra quota production days allowed to the producers. Therefore there is an interest in keeping cows a little longer, bringing in heifers, or buying cows for that period. They also pay more attention to post-partum diseases which can reveal potential problems with the management of the transition period, leading to decreased profitability (LeBlanc, 2010b). If they consider udder health just as much as the other groups, they use surrogates to assess udder health. Somatic cell counts and bulk tank SCC are an efficient way to monitor herd udder health (Schukken et al., 2003); quantifying the clinical and chronic mastitis status of the cow or herd by other means appeared in the present data to be an afterthought. Moreover, they take into account the flow of incoming heifers into the herd, not considered by the 'Animal Welfare Focus' advisers or the producers. They tend to have a global approach to the herd and its economic performance.

Dairy cattle are a reservoir for several zoonotic agents, like *Campylobacter*, *E. coli* O157:H7, *Listeria*, *Coxiella*, and *Salmonella* (Tauxe, 1997). Crohn's and variant Creutzfeld–Jacob diseases in humans could potentially be associated with Johne's disease and bovine spongiform encephalopathy in cows, respectively (Barria et al., 2014; Waddell et al., 2015). And there are growing concerns about the development of antimicrobial resistance in humans due to antibiotic use in livestock (Woolhouse et al., 2015); or the environmental impact of modern agriculture practices (Food Forum et al., 2014; Sørensen et al., 2006). Consumers expect healthy, safe, and sustainable dairy products. This concern is reflected in the decision process of the dairy producers and 'Animal Welfare Focus' advisers. It was also recognized by Young et al. (2010), who found Canadian dairy producers were inclined towards food safety and generally knowledgeable about certain, but not all, infectious agents. While the importance of producing safe, more sustainable food has gained more prominence during the last decade, the preoccupation of farmers for producing healthy and safe products is not new. As shown by Burgess et al. (2000), farmers see themselves as food processors. Therefore it should not be a surprise to see the importance they give to the quality of their production, reflecting the value placed on their role in society (Burton, 2004). If the 'Animal Welfare Focus' advisers follow producers on this matter, 'Economic Focus' advisers are the opposite. This may reflect the departure of one group of advisers from the social value given to dairy farming as an enterprise, often family-driven. 'Economic Focus' advisers have a more 'cold-blooded' view of the dairy enterprise, focusing on the economic aspect of the decision.

Each group also gave a different weight to animal welfare. Our results agree with other studies, where the perception of animal welfare varies across groups of people (Vanhonacker et al., 2008). Producers gave a neutral influence to animal welfare (and milk/meat withdrawal), which could be viewed as contradictory with the importance they give to producing a healthy/safe milk. The relationship producers have with animals is a professional one, where they care about animal welfare but the cows are instrumental to the production of milk (Dockès et al., 2006). The cow's purpose is to produce. Producers are always affected by health disorders of their animals (Dockès et al., 2006). But they want the best for them with the objective of ensuring their productivity (Hansson et al., 2015; McInerney, 2004). As such, procuring the good health of the animals (by checking udder health, producing healthy milk) is how to provide animal welfare, resulting in a neutral position of animal welfare in their decision ranking. Dockès et al. (2006) have shown that if producers see their animals as production tools, advisers are more likely to see them as production tools *and* sentient beings, resulting in three profiles of advisers: (1) animal welfare defines the quality of the relationship between animals and farmers, (2) animal welfare is a production means among others, and (3) animal welfare is part of professional ethics. This division among advisers about animal welfare is found in their decision making process. 'Economic Focus' advisers put forward the animal seen through its production function, with the key economic parameter, reproduction, put first and animal welfare well behind. On the other hand, 'Animal Welfare Focus' advisers might combine the obligation of animals to produce (through the decision parameters related to production, udder health) and the right of the animals to be well treated.

7.5 Conclusion

Our findings suggest that dairy producers and their advisers hold a general common view regarding culling decision-making. Udder health and individual production performances characterized each profile, whereas a subgroup of advisers uses recommendations from economic models in which reproduction status is central for farm profitability. Underlying this general framework are significant differences between producers and advisers, and among the advisers. These differences can impede collaboration between the actors intervening at the farm. Understanding and managing these differences is important to assist the change management processes required to increase farm profitability. Views held by dairy producers and their advisers can influence the success of this relationship both positively and negatively. Understanding the differences in views is critical to managing change processes both in initiating and sustaining collaborations, and deserves further research. A challenge for the future will be the generation of rules of thumb and models that both reflect the complexity of the business and allow the dairy producers an ability to make decisions based on wider criteria that include an economic focus.

Conflict of interest

None.

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Table 7.II – Characteristics of the 41 participating farms (N is the number of non-missing values. Numbers after percents are frequencies).

	N		
Farm size (acres)	41		
<100		5%	(2)
100–199		29%	(12)
200–299		15%	(6)
>299		49%	(20)
Do not know		2%	(1)
Feed	41		
Total mixed ration (TMR)		61%	(25)
Conventional, manual		10%	(4)
Conventional, robot		22%	(9)
TMR and Conventional, robot		5%	(2)
TMR and Other		2%	(1)
Stall type	41		
Free-stall		12%	(5)
Tie-stall		88%	(36)
Production (kg)	41		
7000–8999		17%	(7)
9000–10 999		73%	(30)
≥11 000		10%	(4)
Cull rate (actual, %)	40		
<20		12%	(5)
20–24		12%	(5)
25–29		15%	(6)
30–34		30%	(12)
35–39		18%	(7)
≥40		2%	(1)
Do not know		10%	(4)
Number of employees	40		
0		22%	(9)
0.5		2%	(1)
1		42%	(17)
2		28%	(11)
4		5%	(2)

Table 7.III – Rotated factor loadings of the participating dairy producers on the selected factors.

Q-Sort	F1	F2	h^2
1	0.62**	−0.19	0.42
2	0.7 **	−0.17	0.52
3	0.72**	−0.12	0.53
4	0.73**	0.01	0.54
5	0.82**	−0.03	0.66
6	0.56**	−0.06	0.31
7	0.59**	−0.16	0.37
8	0.7 **	0	0.49
9	0.73**	0	0.53
10	0.47**	0.28	0.31
11	0.55*	0.51*	0.57
12	0.72**	−0.12	0.53
13	0.56**	0.04	0.32
14	0.58**	0.22	0.39
15	0.43**	0.03	0.18
16	0.73**	0.33	0.65
17	0.74**	0.15	0.58
18	0.55**	0.28	0.38
19	0.47*	−0.68*	0.67
20	0.57*	−0.52*	0.59
21	0.52**	−0.4	0.42
22	0.75**	−0.27	0.62
23	0.71**	−0.17	0.53
24	0.39	0.44**	0.35
25	0.5 **	0.23	0.3
26	0.47*	0.47*	0.45
27	0.66**	0.03	0.43
28	0.43*	0.57*	0.53
29	0.57**	0.06	0.33
30	0.48**	−0.02	0.23
31	0.75**	−0.03	0.57
32	0.76**	−0.28	0.65
33	0.73**	0.2	0.58
34	0.84**	−0.1	0.7
35	0.72**	0.17	0.55
36	0.79**	0	0.63
37	0.6 **	0.18	0.39
38	0.81**	0.18	0.69
39	0.43**	0.06	0.19
40	0.48**	0.29	0.32
41	0.77**	−0.04	0.59
Eigenvalues	16.7	2.8	
Variance (%)	40.8	6.9	

Significant loadings (p<0.01) are shown with one star. Defining sorts (sorts which are significant on only one factor) are identified by two stars. h^2 is the sum of squares of factor loadings by rows, eigenvalues are sum of square factor loadings by columns.

Table 7.IV – Rotated factor loadings of the participating farm advisers on the selected factors.

Q-Sort	F1	F2	h^2
1	0.85**	−0.11	0.63
2	0.88**	−0.12	0.68
3	0.89**	−0.27	0.61
4	0.83**	−0.04	0.66
5	0.85**	0.01	0.73
6	0.84**	0.07	0.78
7	0.6 **	0.29	0.63
8	0.52**	0.08	0.32
9	0.78**	0.06	0.66
10	0.42*	0.46*	0.6
11	0.26	0.54**	0.5
12	0.13	0.69**	0.58
13	0.22	0.63**	0.59
14	0.59**	0.33	0.65
15	−0.02	0.85**	0.69
16	0.59**	0.31	0.63
17	0.34	0.57**	0.65
18	0.33	0.58**	0.64
19	0.6 **	0.09	0.42
20	0.52*	0.44*	0.7
21	0.53**	0.29	0.52
22	0.21	0.65**	0.61
23	0.48**	0.35	0.53
24	0.12	0.8 **	0.75
25	0.57**	0.12	0.41
26	0.56*	0.4 *	0.71
27	0.67**	0.32	0.76
28	−0.13	0.7 **	0.41
29	0.31	0.31	0.29
30	0.08	0.61**	0.44
31	0.47**	0.21	0.36
32	0.36	0.49**	0.55
33	−0.43*	0.87*	0.55
34	0.55**	0.31	0.58
35	0.35	0.27	0.3
36	0.44**	0.32	0.44
37	0.46**	0.27	0.41
38	0.13	0.71**	0.61
39	0.34	0.37	0.38
40	0.26	0.42**	0.36
41	0.4 *	0.02	0.17
42	0.85**	−0.06	0.68
Eigenvalues	11.7	8.1	
Variance (%)	27.9	19.2	

Significant loadings (p<0.01) are shown with one star. Defining sorts (sorts which are significant on only one factor) are identified by two stars. h^2 is the sum of squares of factor loadings by rows, eigenvalues are sum of square factor loadings by columns.

CHAPITRE 8

DISCUSSION

L'objectif général de cette thèse était de décrire la réforme des vaches laitières au Québec et d'approfondir les connaissances sur les mécanismes la régissant. L'analyse des différents niveaux d'organisation (vache, troupeau) et de décision (décideurs, conseillers) de la réforme ainsi que des effets contre-factuels et contextuels de plusieurs facteurs de risque distinguent cette étude des précédentes recherches sur la réforme. Cette discussion vise à mettre en relation les principaux résultats des différentes parties de l'étude, d'en discuter les limites et de proposer de futures orientations de recherche.

8.1 Principaux résultats

Cette étude est la première à quantifier les taux de réforme au Québec sur une vaste cohorte observée pendant 10 années. Le taux de réforme a été établi à 32% sur les dix années de suivi de la cohorte, avec un taux de 8,2% lors des soixante premiers jours de lactation. Le Québec présente donc des taux comparables à ce que l'on retrouve ailleurs en Amérique du Nord et notamment dans le nord-est (De Vries et al., 2010 ; Dechow et al., 2008).

Comme rapporté ailleurs dans la littérature (Dechow et al., 2008), des variations importantes de ces taux de réforme sont constatées entre les différents troupeaux. Cette hétérogénéité des troupeaux ne se remarque pas que pour leurs taux de réforme mais aussi pour leurs caractéristiques liées à leurs performances de reproduction, de production, à leur gestion et indicateurs de santé, rendant impossible la détermination de profils spécifiques de troupeaux en fonction de ces caractéristiques. Il est, par contre, possible de les distinguer sur une de ces caractéristiques prises une à une, sans pour autant que cela ne se traduise par une relation particulière entre cet attribut ou les constituants de cet attribut, et le taux de réforme du troupeau.

Les seuls liens mis en évidence l'ont été entre le taux de réforme et les indicateurs de gestion du troupeau d'une part, et ceux de la reproduction d'autre part. Les associations entre le taux de réforme et les incidences de maladies dans le troupeau étaient minimes, et celles avec les performances de production se limitaient à la production laitière du troupeau.

Dans les faits, le taux de réforme est souvent interprété comme un indicateur indirect des performances de production et de reproduction (Dhuyvetter et al., 2007) ou une mesure de la santé du troupeau (Eicker et al., 2003), avec le corollaire qu'un taux de réforme élevé n'est pas souhaitable, nuisant à la rentabilité de l'entreprise, et donc que trop de jeunes vaches sont réformées (Pellerin et al., 2014). Or, que ce soit dans la littérature ou dans la présente étude, soit on ne retrouve pas ces associations soit elles sont inversées.

En effet, si une association entre taux de réforme et reproduction a bien été identifiée dans cette étude, ce l'était entre un taux de réforme élevé et les indices de performance (ou plutôt de non-performance) de reproduction (un taux de gestation réduit, des intervalles de vêlage allongés et une première insémination tardive). Cette association entre la réforme et le délai moyen pour la première insémination du troupeau confirme les résultats de De Vries et al. (2010). L'association trouvée avec l'âge moyen au premier vêlage est aussi retrouvée dans de précédentes études (Ducrocq, 2005 ; Zavadilová et al., 2013). Les performances de reproduction sont un élément essentiels dans la profitabilité de l'exploitation laitière (Boichard, 1990 ; Inchaisri et al., 2010 ; Meadows et al., 2005 ; Oltenacu et al., 1980 ; Plaizier et al., 1998). Un premier vêlage plus précoce permet de réduire les coûts de remplacement (Gardner et al., 1988), ce qui a d'ailleurs amené à la recommandation d'un premier vêlage à 24 mois pour maximiser la production de lait et réduire les coûts d'élevage (Heinrichs, 1993 ; Tozer et al., 2001). Avoir une vache gestante au plus vite après la période d'attente est démontré comme un élément majeur pour la profitabilité de l'exploitation laitière et un élément déterminant dans la décision de réforme lorsque cette gestation se fait attendre (Cabrera, 2012 ; De Vries, 2006a ; Kalantari et al., 2010 ; Meadows et al., 2005 ; Nielsen et al., 2010). Un intervalle de vêlage plus court a aussi un effet bénéfique sur la profitabilité (Schmidt, 1989). Le taux de réforme est donc inversement associé aux performances de reproduction du troupeau et, effectivement, pourrait être considéré comme un indicateur de la rentabilité du troupeau, au moins du point de vue de ses performances de reproduction.

Les troupeaux ayant une production plus importante ont aussi montré des taux de réforme plus élevés, surtout dans l'intervalle des 60ers jours de lactation, rejoignant les résultats de De Vries (2013) et Dechow et al. (2008), même si certaines études n'ont pas démontré la même relation (Pinedo et al., 2010a ; Smith et al., 2000). La relation entre la réforme et la production du troupeau n'est donc probablement pas totalement éclaircie, comme soulevé au chapitre 5. Cependant, si la profitabilité d'un troupeau est mesurée en fonction de son niveau de production, on peut dès lors convenir que le taux de réforme n'est pas un indicateur de cette profitabilité puisque l'on retrouve des taux de réforme plus importants dans les troupeaux les plus producteurs.

Les associations entre la reproduction de la vache (Brickell et al., 2011 ; De Vries et al., 2010 ; Schneider et al., 2007), sa santé (Beaudeau et al., 1994 ; Chiumia et al., 2013 ; Gröhn et al., 1998) et son risque de réforme sont établies au niveau de la vache et ne peuvent être généralisées à une relation collective. Cela peut résulter en un biais atomistique : faire une inférence pour le groupe à partir de données individuelles (Diez Roux, 1998). De même, il ne faut pas tomber dans le piège inverse, le biais écologique, où les inférences au niveau individuel sont basées sur des données au niveau du groupe (Greenland et al., 1994 ; Robinson, 1950). Cette divergence entre le niveau troupeau et le niveau vache a déjà été relevée pour différentes situations dans le cadre de la production des vaches laitières. Par exemple, une production laitière importante est un facteur de risque pour la mammite (Lund et al., 1999) mais les troupeaux constitués de hautes productrices n'ont pas forcément une incidence accrue de mammites (Calus et al., 2005). Le même phénomène a été démontré entre production et fertilité (Bello et al., 2013 ; Windig et al., 2005). Le taux de réforme du troupeau et les facteurs de risque de réforme sont donc un autre exemple où le contexte du groupe peut modifier l'effet des déterminants au niveau individuel (Pearce, 2000). Le lien entre les troubles de la santé de la vache et son risque de réforme est bien établi (Beaudeau et al., 2000 ; Rajala-Schultz et al., 1999a), mais l'utilisation du seul taux de réforme comme indicateur de la santé du troupeau est d'intérêt limité (Eicker et al., 2003). Il est préférable d'utiliser les indicateurs épidémiologiques disponibles (production de lait, CSS, incidences des maladies, intervalles de temps comme par exemple les jours ouverts, etc.) afin d'avoir une approche globale du troupeau (Kelton, 2006). Aussi, l'intérêt du taux de réforme pour évaluer la profitabilité de la ferme laitière serait également discutable, au vu de ses relations incertaines avec les performances de reproduction et de production. Il a d'ailleurs été montré que cet indicateur ne permet pas d'évaluer la performance économique de l'exploitation laitière, au contraire de la production du troupeau et de l'incidence de mammites (Hansson, 2007 ; Huirne et al., 1997). Il convient dès lors d'utiliser le bon indicateur en fonction de l'intention désirée — évaluation économique, sanitaire, de la reproduction, de l'alimentation, etc. du troupeau — et le taux de réforme n'apparaît pas comme le plus pertinent.

La décision de réforme et sa stratégie au niveau du troupeau doivent donc être considérées dans le contexte global de gestion de l'exploitation laitière (Bigras-Poulin et al., 1985 ; Tarabla et al., 1990). Les facteurs tant de troupeau qu'individuels sont importants pour la compréhension des variations de risque aussi bien entre troupeaux qu'entre vaches à l'intérieur de ceux-ci, d'où l'intérêt d'explorer ces différents niveaux d'interprétation (Blakely et al., 2000 ; Diez Roux, 2004 ; Stryhn et al., 2014). L'effet contextuel du troupeau a été identifié dans le risque de réforme, même s'il est limité. Il résulte essentiellement de la pression exercée par les jeunes taures arrivant dans le troupeau en lactation. Il demeure cependant que le risque de réforme se joue principalement au niveau individuel. L'implication est importante pour la compréhension de la réforme. Si une stratégie de réforme est envisagée, on doit d'abord viser à comprendre et gérer les facteurs propres à la vache l'exposant à être réformée. Parmi ceux-ci, on donnera la priorité à l'amélioration de la fertilité et de la fécondité (De Vries et al., 2010 ; Seegers et al., 1998) ainsi qu'à la santé de la glande mammaire (Archer et al., 2013 ; Cha et al., 2013 ; Gröhn et al., 2005 ; Neerhof et al., 2000). Une fois les facteurs de risque individuels maîtrisés, il restera encore au producteur à choisir entre une jeune taure qu'il a élevée et amenée aux portes du troupeau en lactation, et une vache déjà présente dans ce troupeau, les taures de remplacement étant généralement élevées sur place dans le système de production québécois. La stratégie de réforme est donc au moins partiellement pilotée par le choix du producteur d'élever toutes ou la plupart des génisses naissantes dans sa ferme.

L'analyse causale permet de mieux comprendre les interdépendances entre différents facteurs étiologiques afin d'améliorer les décisions d'action ou d'intervention (Pearl, 2002 ; Russo et al., 2011). Le début de la lactation représente un défi métabolique pour la vache, période pendant laquelle elle est le plus à risque de souffrir de problèmes de santé (Drackley, 1999) et ainsi de compromettre sa future production de lait (Rajala-Schultz et al., 1999e). Les différentes maladies survenant en début de lactation sont inter-reliées entre elles (Correa et al., 1993 ; Curtis et al., 1985 ; Erb et al., 1985 ; Peeler et al., 1994). Cette période représente pour la vache une période à risque pour sa réforme (Milian-Suazo et al., 1988 ; Seegers et al., 1998), mais cette période est aussi délicate relativement à la compréhension des évènements de santé s'y manifestant. Parmi ceux-ci, la mammite clinique, se manifestant le plus souvent en début de lactation (Barkema et al., 1998 ; Olde Riekerink et al., 2008 ; Sargeant et al., 1998 ; Suriyasathaporn et al., 2000), a un effet critique sur la production de la vache (Seegers et al., 2003), particulièrement en tout début de la lactation, avant le pic (Lescourret et al., 1994 ; Rajala-Schultz et al., 1999d ; Santos et al., 2004). Les graphes orientés acycliques apportent un support qualitatif à l'étude des relations causales (Greenland et al., 2002 ; Joffe et al., 2012). Ils sont malheureusement trop peu utilisés en épidémiologie vétérinaire (Martin, 2008), notamment dans la littérature sur la réforme, mais ont été systématiquement utilisés ici. Un jeu (minimal) de variables a pu être déterminé pour faire les ajustements entre la réforme et les différentes variables indépendantes (mammite clinique, rétention placentaire, fièvre de lait, déplacement de caillette). La relation de causalité a donc été traitée selon le choix des facteurs de confusion, à partir des connaissances a priori des relations entre les variables en question. Les structures causales présumées sont donc explicites.

La causalité peut également être définie dans un cadre contrefactuel. Dans les études longitudinales, l'effet d'une exposition dépendante du temps sur un évènement de santé s'évalue généralement par des modèles de régression en ajustant pour les facteurs de confusion, qu'ils soient fixes dans le temps, ou dépendant du temps. Cette approche avec des facteurs de confusion dépendant du temps peut produire des résultats biaisés si une covariable prédit à la fois l'évènement d'intérêt et l'exposition ultérieure ; et l'exposition passée prédit cette covariable (Robins et al., 2000). Les résultats sont biaisés car les variables dépendant du temps sont à la fois des facteurs de confusion et des variables intermédiaires. Une solution est d'utiliser la pondération par l'inverse de la probabilité de l'exposition. Cette approche a été appliquée pour déterminer l'effet de la mammite clinique sur la réforme. Le risque de réforme était comparable entre les primipares et les multipares. Ce risque était aussi réduit comparativement à ce qui est retrouvé dans la littérature où le phénomène décrit ci-dessus n'est pas pris en compte. Primipares ou multipares avec une mammite clinique ont donc une chance comparable d'effectuer leur prochaine lactation.

La réforme a ici été envisagée de manière globale, c'est-à-dire correspondant à une sortie du troupeau, sans faire de distinction selon la finalité de la réforme (mortalité, vente au lait, aux fins d'abattage ou d'engraissement). La mortalité était cependant faible (4%). De même, les ventes au lait étaient encore plus limitées (3%), reflétant le fait que beaucoup de troupeaux québécois sont fermés. On peut faire le rapprochement entre les trois finalités et la gravité du facteur de risque ayant conduit à la décision de réforme : extrême pour la mortalité, plus ou moins modérée pour l'abattage et l'engraissement, faible ou absente pour la vente au lait. L'intérêt de séparer ces différentes raisons se rapporte donc plutôt à l'utilisation qui en est faite pour le suivi ou la gestion du troupeau : la mortalité si on est face à un problème de santé, les ventes au lait si c'est une activité économique pour ce troupeau. Les déterminants de la réforme vont aussi varier avec le moment de la lactation. Le risque est le plus élevé au pic de lactation et durant la période d'insémination (Milian-Suazo et al., 1988 ; Seegers et al., 1998). La vache quittera rapidement le troupeau si son pronostic vital est engagé ou si sa production laitière est compromise (Beaudeau et al., 1994 ; Geishauser et al., 1998 ; Gröhn et al., 1998). Par contre, une non gestation pourra conduire à la décision de réforme, dont la mise en oeuvre sera différée pour plus tard ou la vache sera éventuellement autorisée à terminer sa lactation. L'évaluation de la mammite clinique sur la réforme a ici été réalisée à l'aide d'une analyse de survie pour variable dépendante du temps, permettant ainsi de tenir compte du moment de la réforme et de son facteur de risque. Le déplacement de caillette et la fièvre de lait surviennent en début de lactation et la décision de réforme sera généralement prise rapidement, en fonction du pronostic et de la perte en lait encourue. Dans tous les cas, l'appréciation de la production laitière comme variable de confusion est essentielle.

La relation entre la réforme et les performances du troupeau et/ou de la vache, au sens large, n'est pas nécessairement ce qu'elle paraît — absente où on la pressentait, en sens opposé à ce que l'on attendait. Mais alors comment en arrive-t-on à décider qu'une vache doit être réformée ? Y retrouve-t-on dans le processus décisionnel d'autres éléments que les facteurs de risque identifiés ? Ces facteurs de risque ont-ils des poids différents dans la décision ? Et le taux de réforme est-il pris en considération ?

En dépit de la complexité de la réforme, le processus de décision se résume à quelques points qui sont partagés par les différents intervenants à la ferme. Les critères sont très utilitaristes et se concentrent sur la production et l'outil de production : la glande mammaire, la planification de la production, la qualité du produit et la quantité produite. Le taux de réforme du troupeau n'intervient pas dans la décision de réformer une vache particulière. Alors qu'on ne peut établir de profils particuliers de troupeaux, on obtient un profil quasi unique de décision de réforme. Les choix restent donc plutôt empiriques et ne font pas écho aux résultats de modèles mathématiques où la reproduction est prépondérante pour établir un choix entre les animaux et maximiser la profitabilité du troupeau. Malgré leur expérience et discernement, les producteurs sont limités par la perception humaine (Bewley, 2010) et devraient pouvoir profiter de systèmes d'aide à la décision. Ces systèmes doivent cependant pouvoir s'adapter à la variabilité de situations présentes, tant pour le troupeau que l'exploitation en générale et l'exploitant. On est face à une diversité de situation, où un troupeau n'est pas l'autre, où un taux de réforme n'est pas l'autre, et où il ne peut être utilisé ni comme point de comparaison entre troupeaux ni comme une variable substitutive à la profitabilité de l'entreprise. La décision de réforme repose en fait sur le choix du contrefactuel correct. Celui-ci est basé sur les résultats futurs (Burt, 1965 ; Perrin, 1972) alors que le suivi de la production vérifie et analyse les données de production, c'est-à-dire les données historiques, dont fait partie le taux de réforme (Kristensen et al., 2010). Le scénario utilisé dans le processus décisionnel (« *what-if* ») est donc différent selon que l'on évalue l'exploitation ou une vache en particulier (Jonassen, 2012).

L'utilisation d'une approche qualitative, représentée ici par la méthodologie Q, permet d'apporter une flexibilité dans l'appréhension de nouvelles hypothèses, de nouvelles possibilités pour envisager un problème, ou de générer de nouvelles hypothèses. Le contrôle des coûts de production est indispensable en production laitière et dans les élevages en général. L'économie de la santé animale procure le cadre conceptuel, les procédures et les données pour appuyer la prise de décision (Dijkhuizen et al., 1997). Mais dans un système de production qui est essentiellement familial comme au Québec, les décisions seront généralement prises par un seul individu ou le noyau familial. Les préférences personnelles vont dès lors influencer passablement ces décisions. Or cet aspect sera souvent négligé par les approches conventionnelles, que ce soit en économie de la santé animale ou plus généralement en épidémiologie, de part la complexité que les préférences personnelles ajoutent au problème étudié ainsi que l'ajout d'un contexte à prendre en compte, contexte qui va souvent inclure des éléments non quantifiables. Une approche qualitative permet donc d'enrichir une analyse par l'apport d'une sensibilité au contexte social dans lequel les données sont produites. Cependant, la généralisation des résultats obtenus par une méthode qualitative n'est pas toujours généralisable à une autre population ou une autre situation que celles étudiées. Ces résultats peuvent aussi être influencés par la subjectivité ou les biais propres au chercheur.

8.2 Limites de l'étude

Ce projet a fait usage de données observationnelles rétrospectives, provenant d'une part du contrôle laitier (Valacta) et d'autre part du logiciel de suivi de la santé animale utilisé au Québec par les vétérinaires et producteurs (DSA). Ces données sont variées et leur acquisition (par observation), évaluation et enregistrement sont réalisés par plusieurs acteurs qui ne sont pas spécialistes du recueil de données, résultant en une variabilité de la qualité de celles-ci. Par conséquent la présence de différents biais est probable.

La fièvre de lait et le déplacement de caillette sont des évènements rapportés par les vétérinaires et la probabilité d'en manquer le diagnostic est faible. Le mauvais relevé de ces conditions est également considéré comme étant modéré dans les conditions d'utilisation de DSA par les vétérinaires. La même situation est postulée pour le rapport de la réforme, et les vaches sans plus d'information après 580 jours de lactation ont été retirées des jeux de données. La rétention placentaire est souvent rapportée par le producteur. La probabilité de ne pas remarquer cette condition est bien présente, conduisant à une sensibilité moyenne de l'identification de ces cas. La probabilité d'identification et de rapport des conditions étudiées est aussi considérée comme équivalente que l'animal soit réformé ou non. Le biais de classification est fonction de la sensibilité et de la spécificité, dont l'importance relative dépend de la prévalence (de l'issue et de l'exposition) : quand l'exposition est rare, même de petites pertes de spécificité peuvent causer un biais important du risque relatif (Copeland et al., 1977 ; Flegal et al., 1986). La sensibilité n'a par contre qu'un impact négligeable sur ce biais de classification. Nous avons ici des variables dépendante et indépendantes ayant une faible prévalence mais dont la détermination a une spécificité élevée. Le biais de classification est dès lors négligeable (Poole, 1985). La mammite clinique présente par contre une prévalence plus importante, avec une incidence élevée. Dans ce cas également, les biais possibles sont limités (Copeland et al., 1977 ; Greenland, 1980 ; Shy et al., 1978). De plus, le biais de classification a peu d'impact sur les estimés de survie pour une exposition qui présente une bonne probabilité de survie (Sarfati et al., 2010).

Les troupeaux ont été sélectionnés pour leur qualité à rapporter l'information, par exemple en ayant une correspondance suffisante entre les données des deux origines (santé — DSA, production — Valacta), trois années consécutives de suivi avec DSA ou un taux acceptable de notification des différents évènements de santé. Cette sélection des troupeaux en fonction de leur incidence de maladies et de réforme induit cependant un biais de sélection (Greenland et al., 1999 ; Hernán et al., 2004). Les différentes statistiques descriptives de la base de données utilisée concordent cependant avec celles rapportées par Valacta et DSA. Néanmoins, ces deux organismes appliquent sans doute la même approche pour valider leurs données que celle utilisée dans cette étude. Les troupeaux de moins de 30 animaux n'ont également pas été conservés, aucune inférence sur ces troupeaux ne peut donc être faite. On peut cependant émettre l'hypothèse que ces petits troupeaux sont différents du troupeau standard du Québec de 50–60 vaches, requérant une investigation spécifique. On peut remarquer que les biais de sélection peuvent être évalués dans le cadre de graphes orientés acycliques (DAG ; Hernán et al., 2004). On a cependant ici une population formée de vaches à l'intérieur de troupeaux, où des informations concernant celles-ci, et d'autres agrégées au niveau du troupeau, ont permis la sélection tant de vaches dans les troupeaux que des troupeaux eux-mêmes. Cet aspect hiérarchique est seulement en développement dans les DAG (Casini et al., 2011 ; Gebharter, 2014) ; l'approche bayésienne est sans doute une des voies possibles pour gérer ces différents niveaux (Chaix et al., 2011). Une appréciation du biais de sélection a néanmoins été réalisée (Lash et al., 2009), et même si imparfaite, n'a pas révélé de biais significatif.

Dans toute analyse causale, il est important d'identifier les facteurs de confusion à prendre en compte. Cela ne peut être vérifié dans l'absolu, mais des analyses de sensibilité peuvent aider à évaluer les impacts d'une (mauvaise) identification de ces facteurs. Ces analyses de sensibilité, développées pour des modèles de régression logistique avec un seul niveau hiérarchique (Brumback et al., 2004), ne sont pas encore facilement accessible pour les modèles multiniveaux (Kasza et al., 2015) ou de survie (Klungsøyr et al., 2009). L'analyse « causale » réalisée à l'aide d'un modèle marginal structural devrait plutôt être dès lors considéré comme une analyse « moins biaisée » vu qu'elle prend en compte les variables de confusion dépendantes du temps, mais qu'on ne peut prouver que l'on a tenu compte de toutes les variables de confusion.

L'approche méthodologique utilisée pour identifier les critères de décision utilisés par les producteurs et leurs conseillers est par nature exploratoire, utilisant un petit échantillon, non aléatoire, de participants. Ces résultats ne peuvent être généralisés que pour l'échantillon de répondants sélectionnés et non à la population comme dans les études d'enquêtes (Brown, 1980 ; Watts et al., 2012). Cependant, les producteurs et vétérinaires participants sont probablement assez représentatifs de leur groupe qui utilise ou fournit la médecine de population au Québec, et une forte majorité de l'ensemble des conseillers du contrôle laitier ou des meuneries a participé à l'étude. La méthodologie Q n'est pas concernée par la validité externe de ses résultats et se fixe pour objectif d'identifier les structures de pensée sans proposer à quelle fréquence elles sont rencontrées (McKeown et al., 2013 ; Thomas et al., 1992). La généralisation des résultats de la méthodologie Q doit être envisagée dans une étude d'enquête classique. Cependant, le schéma de décision de réforme identifié était très univoque, renforçant la probable généralisation des résultats. On peut aussi suspecter l'introduction d'un biais par l'investigateur, d'une part dans la construction des énoncés de l'échantillon Q, et d'autre part dans l'analyse factorielle de ceux-ci. Le participant a cependant un rôle central dans le classement de ces énoncés. Chacun des énoncés, pris un à un, n'a pas de signification a priori. C'est le participant qui leur donne un sens a posteriori. L'analyse factorielle apporte par contre une part d'appréciation ou de subjectivité de la part de l'investigateur, de par le choix de la rotation effectuée. Ce problème, largement discuté parmi les méthodologistes Q (Brown, 1980 ; Kampen et al., 2013), a peu d'étendue ici vu que la solution apportée par l'analyse factorielle est uniforme, ne faisant ressortir qu'un ou deux facteurs.

Si la décision pour la vache selon les différents acteurs a pu être abordée, la stratégie de réforme pour le troupeau n'a pas été examinée. Les énoncés de l'échantillon Q ne comprenait cependant pas que des éléments individuels mais aussi du troupeau et de l'exploitation. La planification laitière a été un élément répertorié dans les critères important pour la décision. Les connaissances sont toutefois manquantes sur la présence éventuelle d'une stratégie de réforme pour le troupeau, ou si des objectifs de taux de réforme sont établis par les producteurs.

8.3 Directions futures et perspectives de recherche

Cette étude a permis d'explorer les différents niveaux d'interprétation de la réforme ainsi que les relations de causalité en jeu. L'estimation des relations causales dans les études observationnelles demeurent un objectif à atteindre, mais restent néanmoins une difficulté à surmonter (Martin, 2014). Plusieurs méthodes d'analyse causale ont été développées (Hernán et al., 2006), mais leurs applications ne sont pas toujours évidentes et leur utilisation en épidémiologie vétérinaire se fait encore peu fréquente. Surtout, le lien entre analyses causales et méthodes quantitatives (Dohoo, 2008), notamment les modèles multiniveaux, n'est pas encore entièrement réalisé (Martin, 2008). Notamment, les modèles d'analyse contre-factuelle et les graphes acycliques doivent être raffinés pour tenir compte de l'aspect hiérarchique des données (Greenland et al., 2002 ; Oakes, 2004). Pour ce faire, la modélisation bayésienne (Pearl, 2001) ou par équation structurelle (Factor-Litvak et al., 2009) offrent des options pour intégrer les différents niveaux de données dans le cadre contrefactuel.

Nous avons vu que les producteurs et intervenants ont une approche empirique de la décision de réforme et profiterait sans doute d'un outil de décision. Une amélioration pourrait être apportée par l'adoption d'un système d'aide à la décision déjà existant (Cabrera, 2012 ; Groenendaal et al., 2004), éventuellement adapté pour le système de planification de la production. Pondéré par l'expertise factuelle du producteur, il serait déjà probablement suffisant dans la gestion quotidienne du troupeau.

Le producteur pourrait aussi profiter d'un outil de gestion de la réforme, c'est-à-dire d'une évaluation des animaux de remplacement qui lui seront nécessaires. En effet, une certaine proportion des réformes résulte du flux continu de taures qui arrivent dans le troupeau en lactation. Ceci représente cependant une réelle complexité où on doit décider de garder des veaux femelles aujourd'hui en fonction d'une prédiction des futurs besoins de production dans deux ans. Le problème pourrait être étudié via deux approches.

Premièrement, le troupeau de remplacement est souvent peu étudié et sa gestion ne peut que profiter d'une amélioration des connaissances à ce sujet. Certaines sont cependant disponibles pour le Québec ou le Canada, comme concernant la croissance des animaux (Cue et al., 2012 ; Pietersma et al., 2006), leur maturité reproductive (Duplessis et al., 2015) ou la gestion du vêlage (Villetaz Robichaud et al., 2016). Mais les recherches devraient être étendues à la régie d'élevage des génisses et surtout à leur évaluation économique afin d'avoir un portrait complet de cette période d'élevage. Cela permettrait d'apporter les données manquantes à un modèle stochastique comme par exemple celui développé par Mohd Nor et al. (2015).

Ensuite, la réforme des vaches et la gestion des animaux de remplacement pourraient être mises en contexte dans un paradigme différent. En effet, l'élevage des taures de remplacement entraîne des coûts initiaux élevés avec des animaux qui ne rapportent rien avant leur premier vêlage (Mourits et al., 1999). La rentabilité des animaux en lactation est présentement évaluée en incluant les frais liés à eux-mêmes ainsi qu'à l'élevage des animaux qui ne sont pas encore productifs. St-Pierre (2013) a émis l'idée d'évaluer ces deux troupeaux, de remplacement et en lactation, de manière séparée. C'est-à-dire que la ferme laitière n'est plus envisagée comme une entreprise intégrée où les coûts d'alimentation de tous les animaux, en lactation et de remplacement, ne sont supportés que par les animaux en production, mais chacune des entités est évaluée séparément pour sa profitabilité. Cette forme multidivisionnelle, ou forme M (Chandler, 1962), constitue la forme d'organisation de l'entreprise la plus fréquente. Dans cette organisation, l'entreprise est organisée par type de produit ayant sa propre gestion de la production et de la vente. Dans le cas de la ferme laitière, on aurait donc une unité de production de viande et une de lait. L'unité « viande » élève des veaux jusqu'à ce qu'ils deviennent des taures prêtes à vêler. Elles sont alors louées à l'unité « lait » comme outil de production. L'unité « lait » n'est dès lors plus pénalisée par l'amortissement de ces animaux de remplacement. La location de ces animaux est payée en nature à l'unité « viande », avec un veau par année par vache louée. Lorsque la vache n'est plus nécessaire pour l'unité « lait », elle est retournée à l'unité « viande » qui la met en marché (pour un autre troupeau ou pour l'abattoir). Cette approche n'a jamais encore été évaluée formellement ni comparée à l'approche traditionnelle. Dans le cadre d'une spécialisation croissante des entreprises agricoles (O'Donoghue et al., 2011), l'évaluation de la ferme laitière selon cette approche pourrait jeter un éclairage nouveau sur la prise de décision dans la gestion de l'entreprise, la gestion du risque et la rationalisation dans l'élevage laitier (Olynk et al., 2010).

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CHAPITRE 9

CONCLUSION

Cette étude a permis de décrire la réforme dans les troupeaux de vaches laitières du Québec. Les principales conclusions sont les suivantes :

— Le taux moyen de réforme a été établi à 32% sur les dix années de suivi de la cohorte, avec un taux de 8,2% lors des soixante premiers jours de lactation ;

— Des profils de troupeaux ne peuvent être établis à partir d'un ensemble de caractéristiques reliées à leur gestion, performances de reproduction et production, et indicateurs de santé ;

— Par contre, des caractéristiques uniques ont pu être identifiées et peuvent servir de variables contextuelles dans des analyses multiniveaux ;

— Un effet contextuel du troupeau a été identifié dans le risque individuel de réforme, même s'il est limité. Il résulte essentiellement de la pression exercée par les jeunes taures arrivant dans le troupeau en lactation ;

— La mammite clinique est un facteur de risque pour la réforme de la vache, mais avec un effet réduit comparativement aux études antérieures qui ne contrôlaient pas adéquatement les variables de confusion dépendantes du temps ;

— Les primipares et les multipares ont un risque de réforme comparable suite à une mammite clinique, la production de lait ayant moins d'influence chez les primipares que chez les multipares ;

— Les producteurs laitiers et leurs conseillers ont un cadre de décision commun pour réformer une vache, se référant essentiellement à la santé mammaire de la vache et sa production de lait. Un sous-groupe de conseillers utilisent les recommandations de modèles économiques où le statut reproducteur est central à la profitabilité de la ferme.

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Annexe I

Certificat d'éthique à la recherche

Université de Montréal
Comité d'éthique de la recherche en santé

2 novembre 2015

Objet: Certificat d'approbation éthique - 1er renouvellement – « Culling of dairy cows in Québec: Description and model of a decision support system »

M. Denis Haine,

Le Comité d'éthique de la recherche en santé (CERES) a étudié votre demande de renouvellement pour le projet de recherche susmentionné et a délivré le certificat d'éthique demandé suite à la satisfaction des exigences qui prévalent. Vous trouverez ci-joint une copie numérisée de votre certificat; copie également envoyée à votre directeur/directrice de recherche et à la technicienne en gestion de dossiers étudiants (TGDE) de votre département.

Notez qu'il y apparaît une mention relative à un suivi annuel et que le certificat comporte une date de fin de validité. En effet, afin de répondre aux exigences éthiques en vigueur au Canada et à l'Université de Montréal, nous devons exercer un suivi annuel auprès des chercheurs et étudiants-chercheurs.

De manière à rendre ce processus le plus simple possible et afin d'en tirer pour tous le plus grand profit, nous avons élaboré un court questionnaire qui vous permettra à la fois de satisfaire aux exigences du suivi et de nous faire part de vos commentaires et de vos besoins en matière d'éthique en cours de recherche. Ce questionnaire de suivi devra être rempli annuellement jusqu'à la fin du projet et pourra nous être retourné par courriel. La validité de l'approbation éthique est conditionnelle à ce suivi. Sur réception du dernier rapport de suivi en fin de projet, votre dossier sera clos.

Il est entendu que cela ne modifie en rien l'obligation pour le chercheur, tel qu'indiqué sur le certificat d'éthique, de signaler au CERES tout incident grave dès qu'il survient ou de lui faire part de tout changement anticipé au protocole de recherche.

Nous vous prions d'agréer, Madame, Messieurs, l'expression de nos sentiments les meilleurs,

Guillaume Paré
Conseiller en éthique de la recherche.
Comité d'éthique de la recherche en santé (CERES)
Université de Montréal

c.c. Gestion des certificats, BRDV
Jocelyn Dubuc, professeur adjoint, Faculté de médecine vétérinaire - Département des sciences cliniques
Julie Arsenault, professeure adjointe, Faculté de médecine vétérinaire - Département de pathologie et microbiologie
Christine Blondin (Médecine vétérinaire - Cycles supérieurs)
p.j. Certificat #14-016-CERES-D

adresse postale
C.P. 6128, succ. Centre-ville
Montréal QC H3C 3J7

3744 Jean-Brillant
4e étage, bur. 430-11
Montréal QC H3T 1P1

Téléphone : 514-343-6111 poste 2604
ceres@umontreal.ca
www.ceres.umontreal.ca

Université de Montréal

N[O] de certificat
14-016-CERES-D(1)

Comité d'éthique de la recherche en santé

CERTIFICAT D'APPROBATION ÉTHIQUE

- 1er renouvellement -

Le Comité d'éthique de la recherche en santé (CERES), selon les procédures en vigueur et en vertu des documents relatifs au suivi qui lui a été fournis conclu qu'il respecte les règles d'éthique énoncées dans la Politique sur la recherche avec des êtres humains *de l'Université de Montréal*

Projet	
Titre du projet	**Culling of dairy cows in Québec: Description and model of a decision support system**
Étudiant requérant	**Denis Haine** ([redacted]), Candidat au Ph. D. en Sciences vétérinaires (Option Épidémiologie), Faculté de médecine vétérinaire
Sous la direction de	Jocelyn Dubuc, professeur adjoint, Faculté de médecine vétérinaire - Département des sciences cliniques, Université de Montréal & Julie Arsenault, professeure adjointe, Faculté de médecine vétérinaire - Département de pathologie et microbiologie, Université de Montréal.
Autres membres de l'équipe:	Roger Cue, Jonathan Rushton & Émilie Bouchard

Financement	
Organisme	Novalait - FQRNT - Agriculture et agro-alimentaire Canada
Programme	Programme de recherche en partenariat pour l'innovation en production et en transformation laitière-V
Titre de l'octroi si différent	Rentabilité, longévité et taux de réforme chez les vaches laitières
Numéro d'octroi	2012-LT-163341
Chercheur principal	Roger Cue (Université McGill)
No de compte	

MODALITÉS D'APPLICATION

Tout changement anticipé au protocole de recherche doit être communiqué au CERES qui en évaluera l'impact au chapitre de l'éthique. Toute interruption prématurée du projet ou tout incident grave doit être immédiatement signalé au CERES.

Selon les règles universitaires en vigueur, un suivi annuel est minimalement exigé pour maintenir la validité de la présente approbation éthique, et ce, jusqu'à la fin du projet. Le questionnaire de suivi est disponible sur la page web du CERES.

[redacted]

Guillaume Paré [redacted]
Conseiller en éthique de la recherche.
Comité d'éthique de la recherche en santé
Université de Montréal

2 novembre 2015
Date de délivrance du renouvellement ou de la réémission*

1er décembre 2016
Date du prochain suivi

11 mars 2014
Date du certificat initial

1er décembre 2016
Date de fin de validité

*Le présent renouvellement est en continuité avec le précédent certificat

adresse postale
C.P. 6128, succ. Centre-ville
Montréal QC H3C 3J7

3744 Jean-Brillant
4e étage, bur. 430-11
Montréal QC H3T 1P1

Téléphone : 514-343-6111 poste 2604
ceres@umontreal.ca
www.ceres.umontreal.ca