COW'S HEALTH AND FARMER'S ATTITUDE TOWARDS THE CULLING DECISION IN DAIRY HERDS

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COW'S HEALTH AND FARMER'S ATTITUDE TOWARDS THE CULLING DECISION IN DAIRY HERDS

François Beaudeau

Proefschrift

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Beaudeau, F., 1994. Cow's health and farmer's attitude towards the culling decision in dairy herds (Diergezondheid en bedrijfsstijlen in relatie tot afvoerbeslissingen op melkveebedrijven). The study described in this thesis focusses on the health related culling decision in dairy cows, with special attention to the role of farmer's attitude in this process. This thesis is composed of four parts. In the first part, the associations between diseases and culling in dairy cows were reviewed and discussed from the literature. In the second part, the impact of disease on longevity was assessed in terms of risk of culling and in terms of reduced length of productive life. The third part focussed on methodological issues, and proposed a method accounting for within-cow-dependency of lactations to assess diseases as risk factors for culling. The differences between farmers in their culling decision process were specifically studied in the fourth part through the assessment of the associations between farmers' culling decisions and management styles. Applications of the present study and perspectives in the field of herd health management were discussed.

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NN08201, 1886

STELLINGEN

1. Longevity of dairy cows is not necessarily increased by prevention and control of diseases.
   This thesis.

2. Culling is not a biological phenomenon, but results from a human decision. The human dimension should not be omitted in epidemiologic and economic studies regarding animal health care.
   This thesis.

3. The time of culling within the productive life of dairy cows and the culling reasons declared by farmers are the most frequent data available in recording schemes. However, they may not reflect the whole farmers' culling decision process and attitude.
   This thesis.

4. Information provided in this thesis may be useful but is not enough for making culling decisions.
   This thesis.

5. "Before herd averages are used for decision making on individual farms, evidence must be provided that the estimates of disease effects are consistent across herds".
   C. Enevoldsen and Y.T. Gröhn, 7th ISVEE, Nairobi, Kenya, 1994.

6. Facing doubts and uncertainty in your work makes you feel uncomfortable, but leads to creativity.

7. In the scientific world, one can interpret autonomy and independence for loneliness. By nature, to perform a PhD project is not a lonely activity.

8. It would be unfair to consider that only scientific skills are enough to perform and finalize a research project. Organization and reliability in a team contribute as well.

9. One can be tempted to consider the assessment of methods as a main objective of research, even when it is not.

10. "Quant à mes qualités de dessinateur, je n'ai aucune gêne, je me fixe comme exigence que le dessin soit une découverte... Je trouve que le dessin est intéressant quand il ne s'agit pas de dessin. C'est la recherche qui doit être juste, pas le résultat".
Tony Cragg, sculpteur, Interview 1993.

11. "Chaque homme est seul... et nos douleurs sont une île déserte. Ce n'est pas une raison pour ne pas se consoler, ce soir, dans les bruits finissants de la rue, se consoler, ce soir, avec des mots".
Albert Cohen, Le livre à ma mère, Editions Gallimard, 1954.

F. Beaudeau

Cow's health and farmer's attitude towards the culling decision in dairy herds.

Wageningen, 17 January 1995

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To all the people I love.

CONTENTS

GENERAL INTRODUCTION

GENERAL INTRODUCTION

INTRODUCTION

In dairy production systems, farmers have given special attention to the reduction of production costs per produced litre of milk (Noordhuizen et al., 1985), but more specifically since the establishment of the milk quotas in the European Union. Variations between farms in replacement costs suggest possibilities in reducing production costs (Seegers et al., 1994).

Longevity of dairy cows influences the replacement costs. A 5% increase in the culling rate induced a 20% increase in the replacement costs per litre of milk in French Holstein herds (Seegers et al., 1994). An increased longevity of the dairy cows allows to spread the costs of the rearing stage of the unproductive heifer over a higher total milk yield produced during the productive period of the cow. The productive life of cows varies from 1 to 11 lactations in west European dairy production systems, whereas the average number of lactations of culled cows is low: around 3.2 (Renkema and Stelwagen, 1979; Seegers et al., 1990; Beaudeau, 1991).

Regardless of variations in production systems, half of cullings is declared to be decided in relation to the occurrence of health disorders (Young et al., 1983; Sol et al., 1984; Anderson, 1985; Seegers et al., 1994). In that context, a quantitative assessment of the relationships between health disorders and longevity of dairy cows appears to be relevant for identifying target diseases to be included in health monitoring schemes.

Furthermore, large variations between herds, especially in disease incidence, production systems and/or socio-economic environment may influence the culling decision process related to health. Special attention can also be given to the assessment of farmers' culling decision-making in relation to the whole farming system, under the assumption that a similar cow, with the same individual characteristics, especially regarding her disease history, would not be culled in the same manner, whether she belonged to one herd or to another.

OUTLINE OF THE THESIS

The main objective of this study was to investigate the effects of the main diseases occurring in dairy cows on their longevity. Subsequently, the study focussed on the assessment of the influence of farmers' attitudes on culling decision-making.

Chapter 1 reviews the associations between diseases and culling in dairy cows. Attention is focussed on the definition of the diseases investigated, together with the methods used in analyses.

In chapters 2 and 3, the associations between diseases and culling are assessed, using binomial logistic regression, with distinction whether the cows were culled early or later in lactation. In chapter 2, analyses are done on a lactational basis, whereas, in chapter 3, the unit of observation is extended to two consecutive lactations, as an approach to approximate the whole disease history of cows. Therefore, the effects on culling of diseases occurring during two consecutive lactations are investigated.

Attention is focussed on the fact that lactations are not independent within cows, and that cows are not independently distributed within herds for the assessment of individual risk factors for culling (chapter 4). To respect the assumption of independency between observations in logistic regression, a method, based on repeated random selection of one pair of two consecutive lactations per cow, is proposed. Outputs resulting from violating or not the assumption of independency between observations are compared to assess possible biases.

Length of productive life, defined as the number of days between the date of first calving and the date of exit from the herd, is considered in chapter 5 as the measure of longevity to be explained. In order to assess the impact of health disorders on the entire lifespan of dairy cows, survival analysis is used to investigate the relationships between diseases, considered as time-dependent variables, and length of productive life.

Chapters 2 to 5 concentrate on the cow level. In chapter 6, the role of farmers on the individual culling decision is studied. Farmers' points of view towards culling are collected and used to investigate the relationships between their culling decisions and their management styles.

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BIBLIOTHEEK
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CHAPTER 1

ASSOCIATIONS BETWEEN HEALTH DISORDERS AND CULLING OF DAIRY COWS: A REVIEW

F. Beaudeau, A. Henken, C. Fourichon, K. Frankena, H. Seegers

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ASSOCIATIONS BETWEEN HEALTH DISORDERS AND CULLING OF DAIRY COWS: A REVIEW

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ABSTRACT

Research into the relationships between diseases of cows and culling in dairy herds is reviewed with emphasis on both results and their factors of variation. Tables provide comparisons between studies depending on their designs and their results.

Differences between the study populations are outlined. The studied health disorders are extensively reported and their risks of misclassification are discussed. The other variables considered as possible risk factors for culling are reviewed. Some individual characteristics of cows (age, milk production level, reproductive performances) are usually taken into account in the analyses, whereas the herd effect on the individual risk of culling is poorly documented. The statistical methods for the analysis of health disorders as risk factors for culling are summarized.

Certain health disorders (dystocia, mastitis) increase the risk of culling regardless of the production systems considered. However, for other health disorders (milk fever, metritis, cystic ovaries, retained placenta, locomotor disorders), contradictory results are reported. These discrepancies may result from either actual differences in the production systems studied or differences in methodologies used.

The interest of further studies investigating especially the herd effect on the individual risk of culling is displayed.

Key words: dairy cow, culling, disease, epidemiological risk factors

INTRODUCTION

Health disorders of dairy cows have a great impact on farm profit. They increase direct disease related costs (e.g. losses due to death, costs for drug treatment and veterinary fees) and indirect disease related costs (e.g. reduced milk receipts, reduced slaughter value, low genetic progress). Losses caused by health problems in dairy herds have been estimated at Dfl. 400 per cow present per year in the Netherlands (Dijkhuizen, 1983).

The economic impact of diseases through anticipated cullings appears to be particularly high. Half of the cullings are decided involuntarily and are anticipated because of health disorders (Allaire et al., 1977; Young et al., 1983; Dohoo and Martin, 1984c; Sol et al., 1984; Van Arendonk et al., 1984; Anderson, 1985). The loss due to a forced replacement of a cow varies from 460 to 1200 Dfl. depending on the culling reason (Sol et al., 1984). Moreover, the possibilities of disposal based on voluntary replacement and selection are limited by involuntary cullings.

To assess the economic impact of diseases through cullings, quantitative parameters are needed. An investigation into the influence of health disorders on culling may provide some of them.

The present paper is therefore focused on the relationships between health disorders and culling of dairy cows by literature review in order to quantify possible relationships.

STUDY DESIGNS USED IN INVESTIGATION INTO RISK FACTORS FOR CULLING

Risk assessment for culling is not frequently reported in the literature. Moreover, differences between studies, with respect to precise objectives and study populations, materials and methods (variables studied, time frame of study, methods of analysis) prohibit a direct comparison and thus necessitate a comprehensive analysis of the protocol of each study (Tables 1 and 2).

Objectives and study populations

All the studies in which relationships between health disorders and culling have been investigated as either a primary or a secondary objective, are considered in this paper. Some studies focused specifically on the role of health disorders in the risk for culling, most often in association with milk production and/or reproductive performance (Cobo-Abreu et al., 1979b; Martin et al., 1982; Dohoo and Martin, 1984c; Bigras-Poulin, 1985; Erb et al., 1985; Gröhn and Saloniemi, 1986; Milian-Suazo et al., 1988; Bendixen and Åstrand, 1989; Oltenacu et al., 1990) . The main objective of Bendixen (1988) was to describe the occurrence of diseases and the relationships between diseases, and thus not principally on the relationships between diseases and culling.

All studies showed the effects of risk factors on culling as a crude event. Few studies investigated the relationships between risk factors (diseases and others) and specific culling reasons (Martin et al., 1982; Oltenacu et al., 1984; Milian-Suazo et al., 1989). All studies were longitudinal and prospective using observational-analytic methods. Table 1 gives the main characteristics of the populations chosen in each study.

Table 1. A description of materials and methods used in the literature on diseases as risk factors for culling: objective, study populations and samples involved

Objective[1]	Studies				Authors
	Countries	Study period	Sample size	Breed (s)[2]	
Main	Canada	from 1969 to 1977	1 herd	HF	Cobo-Abreu et al. (1979b)
Main	Canada	from 1977 to 1978	18 herds	HF	Martin et al. (1982)
Main	Canada	from 1979 to 1981	2875 lactations 32 herds	HF	Dohoo and Martin (1984c)
Main	USA	from 1976 to 1977	492 lactations 8 herds	HF	Oltenacu et al. (1984)
Main	Canada	from 1981 to 1983	2004 lactations 34 herds	HF	Bigras-Poulin (1985)
Main	USA	from 1981 to 1983	2850 lactations 33 herds	HF	Erb et al. (1985)
Main	Finland	1983	73 368 lactations	Ayrshire	Gröhn and Saloniemi (1986)
Secondary	Sweden	from 1970 to 1974	153 991 lactations	SRB SLB	Bendixen (1988)
Main	USA	from 1981 to 1985	7763 lactations 34 herds	HF	Milian-Suazo et al. (1988)
Main	Sweden	from 1980 to 1974	21 266 lactations	SLB	Bendixen and Åstrand (1989)
Main	Sweden	from 1983 to 1985	109 010 lactations	SRB SLB	Oltenacu et al. (1990)

[1]"main" means "focused specifically on the role of health disorders in the risk for culling"; "secondary" means "not focused principally on the role of health disorders in the risk for culling".
[2]HF: Holstein Friesian; SRB: Swedish Red and White; SLB: Swedish Friesian.

Table 2. A description of materials and methods used in the literature on diseases as risk factors for culling: time frame, variables under study and data recorder

Time frame	Health disorders		Other variables	Data recorder	Authors
	Number	Topics	Topics		
Life-span	10	Various	Age	-	Cobo-Abreu et al. (1979b)
Two lactations	11	Various	Age Milk production Herd	Veterinarian and/or farmer	Martin et al. (1982)
One lactation	22	Various	Age Milk production Herd	Veterinarian and/or farmer	Dohoo and Martin (1984c)
One lactation	3	Periparturient health disorders	Parity	Veterinarian	Oltenacu et al. (1984)
One lactation	11	Various	Age Herd	Veterinarian and/or farmer	Bigras-Poulin (1985)
One lactation	5	Periparturient health disorders	Age Milk production Reproductive performance Herd	Veterinarian and/or farmer	Erb et al. (1985)
One lactation	4	Various	Parity Calving season Herd milk production	Veterinarian	Gröhn and Saloniemi (1986)
One lactation	6	Periparturient health disorders	Parity	Farmer	Bendixen (1988)
One lactation	14	Various	Parity Calving season Milk production Reproductive performance Herd	Veterinarian and/or farmer	Milian-Suazo et al. (1988)
One lactation	1	Mastitis	Parity	Farmer	Bendixen and Åstrand (1989)
One lactation	8	Periparturient health disorders	Age Calving season Herd milk production	Veterinarian and/or AI technician	Oltenacu et al. (1990)

The studies were performed in North American and Nordic countries and concerned especially Holstein Friesian cows. Data were collected in the seventies and in the first half of the eighties. Sample size varied largely between studies, depending on the number of dairy herds involved, the average number of dairy cows per herd and the duration of the study period. The Nordic studies were based on data collected through comprehensive state surveillance programs for diseases and were characterized by large samples. The other studies involved fewer animals and were performed in 8 (Oltenacu et al., 1984), 18 (Martin et al., 1982) and approximately 30 dairy herds (Dohoo and Martin, 1984c; Bigras-Poulin, 1985; Erb et al., 1985; Milian-Suazo et al., 1988, 1989) respectively. Cobo-Abreu et al. (1979b) observed a cohort during 6 years in one university dairy herd. Given the incidence rate of the main diseases and the total annual culling rate, such sample sizes were sufficient, when investigating culling as a crude event. However, when risk factors for reason-specific culling were investigated, the number of observations was a limiting factor.

Variables under study

Health disorders

Differences between studies according to the number and the type of health disorders existed. Cobo-Abreu et al. (1979b), Martin et al. (1982), Dohoo and Martin (1984c), Bigras-Poulin (1985), Milian-Suazo et al. (1988, 1989) investigated effects of 10 to 22 diseases. Oltenacu et al. (1984), Erb et al. (1985), Bendixen (1988), Oltenacu et al. (1990) restricted their studies to periparturient health disorders (metritis, cystic ovaries, dystocia, retained placenta, parturient paresis and milk fever). Bendixen and Åstrand (1989) studied the effects of clinical mastitis specifically. Also, no homogeneity in the definition of a disease between the studies existed. The different definitions of a disease status can lead to misclassification bias within a study and can limit comparisons between studies. The false-negatives and the false-positives can be numerous, since the diagnosis can be subjective and the criteria for diagnosis can differ from one farmer or veterinarian to another. Furthermore, the recordings are largely dependent on the owners' willingness to cooperate and may vary from one production system and population structure to another (Emanuelson, 1988).

A diagnosis could be made by the farmer alone (Bendixen, 1988; Bendixen and Åstrand, 1989), by the farmer in collaboration with the veterinarian (Martin et al., 1982; Dohoo and Martin, 1984c; Erb et al., 1985; Milian-Suazo et al., 1988, 1989), by the veterinarian alone (Oltenacu et al.,1984; Gröhn and Saloniemi, 1986) and by the veterinarian or the AI technician (Oltenacu et al., 1990).

Relationships between diseases are well-documented (Dohoo and Martin, 1984a; Bigras-Poulin, 1985; Bigras-Poulin et al., 1990b; Faye et al., 1986b; Rowlands et al., 1986; Saloniemi et al., 1986; Syväjärvi et al., 1986; Bendixen, 1988; Markusfeld, 1990; Gröhn et al., 1989, 1990a, 1990b). Therefore, each health disorder as a risk factor for culling has been considered after controlling the possible effect of the other diseases, in all studies.

However, the studies never took into account the cumulative effect of the occurrence of several diseases within a lactation.

Other variables

The role of health disorders as possible risk factors for culling was sometimes investigated without considering any other individual criterion (Milian-Suazo et al., 1988). In most of the studies, however, other individual characteristics of a cow were included in the analysis. These other characteristics were analysed as main effects or as confounders with the hypothesis that they may be related both to diseases and to culling. In this way, different variables may be considered as relevant.

The age or parity of a cow was often treated as a potential confounder. Burnside et al. (1971), Cobo-Abreu et al. (1979a), Martin et al. (1982), Gartner (1983), Sol et al. (1984) found that age-specific culling rates increased with age. Moreover, age and parity were associated with an increase in risk of health disorders (Erb and Martin, 1980; Dohoo et al., 1984d; Bigras-Poulin, 1985; Faye et al., 1986a; Bendixen, 1988). Thus, in all the available studies, age or parity were included as confounders in the analyses. Some authors performed separate analyses, for primiparous and multiparous cows (Oltenacu et al.,1984, Erb et al., 1985; Oltenacu et al., 1990). Others, like Bigras-Poulin (1985), Erb et al. (1985) and Gröhn and Saloniemi (1986) considered age as a main effect.

At least 20 % of the culled dairy cows are eliminated for low milk production (Brocklehurst, 1982; Dohoo and Martin, 1984c, Sol et al., 1984, Milian-Suazo et al., 1989). Many authors showed possible associations between diseases and milk production (Cobo-Abreu et al., 1979b; Erb et al., 1981a, 1981b; Martin et al., 1982; Thompson et al., 1983; Dohoo and Martin, 1984b; Lucey and Rowlands, 1984; Bigras-Poulin, 1985, 1990a). Considering the hypothesis that disease could be an indirect risk factor for culling, mediated through milk production, milk production level was therefore included as a confounder or as a main effect in many studies. Different milk production parameters were considered such as breed class average for milk (Martin et al., 1982; Dohoo and Martin, 1984c), previous and current-lactation total milk yield, previous-lactation milk yield per day of calving interval and current-lactation milk yield per day in milk, current-lactation days in milk, estimated transmitting ability (Milian-Suazo et al., 1989), mature equivalent milk level and estimated transmitting ability for the primiparous (Erb et al., 1985).

Only two studies took into account the reproductive performance of a cow, although the most frequent culling reason is usually "failure to conceive". Some reproductive diseases are associated with breeding performance (Sandals et al., 1979; Fonseca et al., 1983; Oltenacu et al., 1983; Thompson et al., 1983; Dohoo and Martin, 1984c; Halpern et al., 1985). Therefore, breeding performances such as days to first service, conception at first service (Erb et al., 1985), number of services (Erb et al., 1985; Milian-Suazo et al., 1989) were considered as possible direct risk factors for culling.

Some studies also included a season effect. Month-specific culling rates vary from one month to another (Burnside et al., 1971; Sol et al., 1984; Anderson, 1985; Crosse and O'Donovan, 1989). Moreover, significant peaks are found in the occurrence of some health disorders during particular seasons (Erb and Martin, 1978; Eddy and Scott, 1980; Erb and Martin, 1980; Dohoo et al., 1984d; Faye et al., 1986a). Therefore, calving month as a confounder (Oltenacu et al., 1990) or calving season as a main effect (Gröhn and Saloniemi, 1986, Milian-Suazo et al., 1989) were sometimes included in the analysis of the risk of culling.

Not only time as such but stage of lactation of disease occurrence was also studied for mastitis (Bendixen and Åstrand, 1989).

Several reasons may lead to include a "herd" effect in the analysis. Cows in different herds with identical individual risk factors may not have the same probability of culling (Curtis et al., 1988). Individual culling decisions may be highly dependent on the specific environment of the herd. Furthermore, culling of a particular cow may not only depend on her own characteristics but also on the characteristics of the other cows in the herd and on events occurring at the herd level. The herd effect was mostly controlled for by either forcing N-1 variables representing the N herds involved (Dohoo and Martin, 1984c; Bigras-Poulin, 1985, Milian-Suazo et al., 1989), or by expressing individual continuous variables as deviations from the herdmate average (Erb et al., 1985), e.g. herd average milk production (Martin et al., 1982). In these cases, the specific origins of the herd effect were not investigated, since no specific herd characteristics were included as risk factors for culling. Several studies tended to contribute to the explanation of the herd effect. Gröhn and Saloniemi (1986) and Oltenacu et al. (1990) included in their models the herd milk yield level as risk factor for culling. Nevertheless, on the whole, contributions to the investigation of herd effect on the individual risk of culling are rare.

Time periods of observation

Three different time frames could be distinguished. The common assumption was that culling decisions depend not only on the last disease a cow has experienced in the current lactation but also on all the other health disorders experienced all along the current lactation. Therefore, all authors focused on the role of health disorders in the same lactation (Cobo-Abreu et al., 1979b; Martin et al., 1982; Dohoo and Martin, 1984c; Erb et al., 1985; Bigras-Poulin, 1985; Gröhn and Saloniemi, 1986; Bendixen, 1988; Bendixen and Åstrand, 1989; Milian-Suazo et al., 1989; Oltenacu et al, 1990). In addition, Cobo-Abreu et al. (1979b) extended their time frame to all health disorders experienced in life before culling (i. e. diseases the cow had at some time experienced) in a cohort study. Martin et al. (1982) restricted their analysis to diseases occurring in the current and previous lactation.

Statistical analysis

Several methods of analysis were used to quantify the risk of culling related to the main health disorders. Disease-specific relative risks could be calculated (Milian-Suazo et al., 1988) with parity-adjustment (Bendixen, 1988; Bendixen and Åstrand, 1989). Cobo-Abreu et al. (1979b) and Oltenacu et al. (1984) calculated parity-stratified odds ratio in order to quantify the associations. Discriminant analyses (Martin et al., 1982; Dohoo and Martin, 1984c), ordinary logistic regression (Gröhn and Saloniemi, 1986, Milian-Suazo et al., 1989), stepwise logistic regression (Bigras-Poulin, 1985), logistic regression combined with path analysis (Erb et al., 1985; Oltenacu et al., 1990) were used. Quantitative multivariate methods are suitable to include many possible risk factors in the same model and to quantify the effect of each factor, taking into account the effects of the other ones. Irrespective from the method of analysis, the association between disease and culling was quantified and expressed as relative risk (RR) or odds ratio (OR).

Path analysis provides the opportunity to decompose the influence of diseases on risk of culling in direct and indirect effects. Erb et al. (1985) considered that the reproductive disorders could be associated with culling both directly and also through the mediation of some reproductive performances. Therefore, the logistic path analysis consists in drawing and testing the path between possible risk factors and their "effects", for which there could be a biological justification. For example, both the direct effect of metritis on culling and its indirect effect through an increased number of services were tested. Therefore, the logistic path model provides the magnitude of the direct and indirect associations with culling by using odds ratios. Also, some diseases could be considered as indirect risk factors for culling.

RESULTS AND DISCUSSION

Relative rates of health disorders as culling reasons

Certain reasons related to health disorders, such as breeding problems, mastitis and foot disorders were always mentioned in the studies describing culling. Definition and classification of the culling reasons varied between studies. O'Bleness and Van Vleck (1962), Young et al. (1983), Dohoo and Martin (1984c) differentiated mastitis from udder problems as such and teat injuries. Burnside et al. (1971) and Anderson (1985) reported the reason "disease". Brucellosis was cited as reason of disposal in a few studies (O'Bleness and Van Vleck,1962; Howe, 1974; Crosse and O'Donovan, 1989). The results of these studies are hardly comparable because of the various reasons given by the authors and the lack of homogeneity in the definition of these reasons. Nevertheless, general trends appear in all the studies. Table 3 gives the relative importance of the main reasons for disposal.

Table 3. Relative rates of the main culling reasons (%)

Studies				Culling reasons							Authors
Countries	Breed (s)	Study period	Cows (herds)	Breeding failure	Low production	Mastitis	Age	Locomotor problems	Others related to health	Miscellaneous	
USA	-	from 1933 to 1972	8722	39	18	16	-	-	17	10	Allaire et al. (1977)
NZ	-	from 1981 to 1982	(72)	31	19	10	-	2	3	35	Anderson (1985)
USA	-	from 1976 to 1980	(33 - 45)	29	25	9	-	3	8	26	Brocklehurst (1982)
CAN	Ayrshire Guernsey Holstein Jersey	from 1967 to 1968	26651	20	19	5	-	3	12	41	Burnside et al. (1971)
IRL	-	from 1980 to 1985	-	25	22	12	3	5	19	14	Crosse and O'Donovan (1989)
CAN	Holstein Friesian	from 1979 to 1981	(32)	17	20	16[1]	-	5	9	33	Dohoo and Martin (1984c)
UK	Holstein Friesian	from 1973 to 1976	794	36	16	13	4	8[3]	7	16	Gartner (1983)
UK	-	from 1972 to 1973	25012	31	20	10	6	2	13	18	Howe (1974)
USA	Holstein Friesian	from 1981 to 1985	1449	25	21	22[1]	2	7	-	23	Milian-Suazo et al. (1989)
USA	5 breeds	from 1960 to 1961	7362	16	27	8	7	3	6	33	O'Bleness and van Vleck (1962)
NL	-	from 1974 to 1977	(30)	23	23	17[2]	5	7	13	12	Sol et al. (1984)
NL	Holstein Friesian Dutch Friesian Dutch Red & White	from 1973 to 1982	(2)	40	17	24[1]	-	9	-	10	Van Arendonk et al. (1984)
GB	Holstein Friesian	1974	8085	29	16	13	5	3	21	13	Young et al. (1983)

[1]mastitis and udder problems.
[2]mastitis and teat injuries.
[3]locomotor problems, injuries and accidents.

Breeding problems are the main reason for disposal (from 16 to 36 % of the culled cows). Low milk production is also an important reason (from 16 to 25 % of the culled cows), followed by the disposal for mastitis (from 5 to 16 %). Regardless of the production system studied, at least 50 % of the disposals are related to health disorders.

Relationships between health disorders and specific culling reasons

Given the previous results, one may assume that there is a significant relationship between a particular disease and the reason for culling of that cow. Few studies have been done to investigate these specific relationships (Martin et al., 1982; Oltenacu et al., 1984; Milian-Suazo et al., 1989). Milian-Suazo et al. (1989), in a comprehensive study, found associations consistent with biological assumptions. Downer cow syndrome was associated with an increased risk of death, mastitis and teat problems with culling for udder disorders, cystic ovaries and abortion with culling for poor reproduction, foot and leg problems with culling for locomotor disorders and left abomasal displacement with culling for miscellaneous reasons. Martin et al. (1982) reported that a cow having experienced mastitis or lameness in the current lactation had a significantly increased risk of being culled for the culling reasons "mastitis" and "foot problems" respectively. However, occurrence of mastitis or reproductive problems did not significantly increase the risk of culling for reasons of "udder problems" and "reproductive problems", respectively, in the current lactation. Oltenacu et al. (1984) investigated the relationships between the health status of cows and their reason for culling and concluded that there was no statistical significant association.

The associations between health disorders and specific reasons for culling were poorly documented. Moreover, the divergent results showed that except for a few obvious and direct relationships, the associations between diseases and culling were complex. An explanation could be that "to use a farmer's stated reason of culling provides information about the most immediate and pressing shortcoming of that cow" (Dohoo and Martin, 1984c).

Relationships between health disorders and the general risk of culling

The evaluation of the role of disease history as a direct or an indirect risk factor for culling as crude event was the most commonly reported in the literature. In a general study, Oltenacu et al. (1984) showed that a higher risk of culling was associated with a poor health status, both in primiparous and multiparous cows. Other studies provided more detailed results. Table 4 gives the values of the odds ratios or relative risks for each main disease.

For some diseases, general trends appear, whereas for other health disorders contradictory effects are observed. These discrepancies may result from either differences in methods or from actual differences in the production systems studied.

Reproductive disorders

Many reproductive disorders have been investigated as possible risk factors for culling. Some disorders were well-defined, but a lack of homogeneity for others (metritis, parturient paresis, retained placenta) could lead to misclassification. Furthermore, a broad term like "infertility" (Gröhn and Saloniemi, 1986) has to be treated separately.

"Infertility" was found to be protective for culling by Gröhn and Saloniemi (1986), in conflict with the fact that infertility was a major culling reason. The odds ratio of less than unity may be due to the study design used, since each cow was under observation from 2 days before calving to 305 days post-partum, in relation with the definition of "infertility" (including ovary dysfunction, anoestrus, suboestrus, infection of the reproductive tract post-partum and other infertility). In fact, it could be expected that cows with subfertility and delayed oestrus were not culled within 305 days post-partum, especially if their level of milk production was high.

There was no conclusive effect of metritis on culling. A positive association was found by most of the authors, and the strength of this association remained constant from one study to the other (Cobo-Abreu et al., 1979b, Martin et al., 1982, Bigras-Poulin, 1985, Milian-Suazo et al., 1988, Oltenacu et al., 1990). However, late metritis (diagnosed after 60 days post-partum) was found protective for culling before 150 days post-partum. This could be explained by the combined effect of both the particular definition of this disorder and the time of culling in the lactation. In other words, only cows not destined to be culled were examined for this disease (Dohoo and Martin, 1984c). Erb et al. (1985) found no direct association between metritis and risk of culling in both primiparous and multiparous cows. These contradictory results show the particular importance of the methodological choices (lactation days at risk, definition of types of metritis, inclusion of breeding performances as risk factors in the analysis) for the investigation of health disorders as risk factors for culling.

In the same way, the actual effects of cystic ovaries as risk factors for culling were not clear. Various values of risk, both in the trend of the relation and in its strength, were found in Holstein Friesian cows and for different study periods. A direct positive association between cystic ovaries and culling was found by Bigras-Poulin (1985), Erb et al. (1985) (in multiparous cows) and Oltenacu et al. (1990), whereas Cobo-Abreu et al. (1979b), Dohoo and Martin (1984c) and Erb et al. (1985) (in primiparous cows) found no direct significant association. Moreover, Martin et al. (1982) found that cystic ovaries were protective for culling in the same lactation. An explanation might be that cows with ovarian disease were milked significantly longer and tended to produce more milk. Erb et al. (1981a, 1981b), Dohoo and Martin (1984b) also found that cows with cystic ovaries yielded significantly more milk.

As a general rule, dystocia was a direct risk factor for culling, regardless of the definition of the disorder. Nevertheless, Martin et al. (1982) and Dohoo and Martin (1984c) found no association between dystocia and culling in the same lactation. However, when data from two lactations were used, dystocia in the previous lactation increased the risk of culling in the current lactation (Martin et al., 1982).

The investigation of retained placenta as a risk factor for culling showed contrasting results. In most cases, cows with retained placenta had at least a 1.2 times greater risk of being culled than cows without this disease. Nevertheless, no direct association between retained placenta and culling was found by Martin et al. (1982), Dohoo and Martin (1984c), and Erb et al. (1985).

Despite the different breeds involved, parturient paresis appeared to be associated with an increased risk of culling (Gröhn and Saloniemi, 1986; Bendixen, 1988), except for Friesian cows having experienced either dystocia and/or retained placenta (Bendixen, 1988). For milk fever, contrasts could be noticed. Firstly, there were contradictory results in the trend of the relationship since milk fever was found to be positively associated with culling by Dohoo and Martin (1984c) and Milian-Suazo et al. (1988), negatively associated by Bigras-Poulin (1985) and not associated by Cobo-Abreu (1979b), Martin et al. (1982), Erb et al. (1985). Secondly, the strength of the relationship varied highly from one study to another, especially for the "milk fever cow down".

Table 4. Relationships between main health disorders and culling

Health disorders	Risk of culling[1]	Studies: Specific definitions and/or sub-populations involved[2]	Authors
Infertility	OR = 0.7		Gröhn and Saloniemi (1986)
Metritis	OR = 4.1		Cobo-Abreu et al. (1979b)
	(+)		Martin et al. (1982)
	(-)	diagnosis after 60 d - sales after 150 d pp	Dohoo and Martin (1984c)
	(-)	diagnosis after 20 d - culling before 150 d pp	Dohoo and Martin (1984c)
	OR = 1.5		Bigras-Poulin (1985)
	NS	primiparous	Erb et al. (1985)
	NS	multiparous	Erb et al. (1985)
	RR = 1.2		Milian-Suazo et al. (1988)
	RR = 1.7		Milian-Suazo et al. (1988)
	RR = 1.4	primiparous	Oltenacu et al. (1990)
	RR = 1.2	multiparous	Oltenacu et al. (1990)
Cystic ovaries	NS		Cobo-Abreu et al. (1979b)
	(-)		Martin et al. (1982)
	NS		Dohoo and Martin (1984c)
	OR = 2.9		Bigras-Poulin (1985)
	NS	primiparous	Erb et al. (1985)
	OR = 1.5	multiparous	Erb et al. (1985)
	RR = 1.1		Milian-Suazo et al. (1988)
	OR = 2.6	primiparous	Oltenacu et al. (1990)
	OR = 3.2	primiparous	Oltenacu et al. (1990)
Dystocia	(+)	occurrence in the previous lactation	Martin et al. (1982)
	NS		Dohoo and Martin (1984c)
	OR = 2.9	primiparous	Erb et al. (1985)
	OR = 3.7	multiparous - with veterinary assistance	Erb et al. (1985)
	RR = 1.7	SRB	Bendixen (1988)
	RR = 1.8	SLB	Bendixen (1988)
	RR = 1.5		Milian-Suazo et al. (1988)
	OR = 1.7	primiparous	Oltenacu et al. (1990)
	OR = 1.5	primiparous	Oltenacu et al. (1990)
Retained placenta	OR = 2.3		Cobo-Abreu et al. (1979b)
	NS		Martin et al. (1982)
	NS		Dohoo and Martin (1984c)
	OR = 1.8		Bigras-Poulin (1985)
	NS	primiparous	Erb et al. (1985)
	NS	multiparous	Erb et al. (1985)
	RR = 1.5	without parturient paresis and/or dystocia - SRB	Bendixen (1988)
	RR = 1.2	with parturient paresis and/or dystocia - SRB	Bendixen (1988)
	RR = 1.4	without parturient paresis and/or dystocia - SLB	Bendixen (1988)
	NS	with parturient paresis and/or dystocia - SLB	Bendixen (1988)
	RR = 1.6		Milian-Suazo et al. (1988)
	OR = 1.4	primiparous	Oltenacu et al. (1990)
	OR = 1.2	primiparous	Oltenacu et al. (1990)
Parturient paresis	RR = 1.9	without any definition	Gröhn and Saloniemi (1986)
	RR = 1.6	without dystocia and/or retained placenta - SRB	Bendixen (1988)
	RR = 1.2	with dystocia and/or retained placenta - SRB	Bendixen (1988)
	RR = 1.5	without dystocia and/or retained placenta - SLB	Bendixen (1988)
	NS	with dystocia and/or retained placenta - SLB	Bendixen (1988)

[1]RR: relative risk; OR: odds ratio; (+): positive association (discriminant analysis); (-): negative association (discriminant analysis); NS: no significant association; [2]d: days; pp: post-partum; SRB: Swedish Red and White breed; SLB: Swedish Friesian breed.

Health disorders	Risk of culling[1]	Studies Specific definitions and/or sub-populations involved[2]	Authors
Milk fever	NS		Cobo-Abreu et al. (1979b)
	NS		Martin et al. (1982)
	RR = 18.8	cow down	Dohoo and Martin (1984c)
	NS	cow not down	Dohoo and Martin (1984c)
	OR = 0.5		Bigras-Poulin (1985)
	NS	primiparous	Erb et al. (1985)
	NS	multiparous	Erb et al. (1985)
	RR = 3.5	cow down	Milian-Suazo et al. (1988)
	RR = 1.5	cow not down	Milian-Suazo et al. (1988)
Abortion	NS		Dohoo and Martin (1984c)
	OR = 21.3		Bigras-Poulin (1985)
	RR = 1.9		Milian-Suazo et al. (1988)
Stillbirth	OR = 1.3	primiparous	Oltenacu et al. (1990)
	NS	primiparous	Oltenacu et al. (1990)
Mastitis	OR = 5.0		Cobo-Abreu et al. (1979b)
	NS		Martin et al. (1982)
	RR = 30.8	systemic therapy - culling before 150 d pp	Dohoo and Martin (1984c)
	RR = 3.6	local therapy - culling before 150 d pp	Dohoo and Martin (1984c)
	OR = 1.8		Bigras-Poulin (1985)
	OR = 5.2	primiparous	Erb et al. (1985)
	OR = 2.1	multiparous	Erb et al. (1985)
	OR = 1.6		Gröhn and Saloniemi (1986)
	RR = 2.9	SRB	Bendixen (1988)
	RR = 2.8	SLB	Bendixen (1988)
	RR = 2.0		Milian-Suazo et al. (1988)
Subclinical mastitis	(+)	culling and sales after 150 d pp	Dohoo and Martin (1984c)
Teat injuries	RR = 21.1	culling before 150 d pp	Dohoo and Martin (1984c)
	NS		Bigras-Poulin (1985)
	RR = 2.2	without previous occurrence of mastitis - SRB	Bendixen (1988)
	RR = 2.0	with previous occurrence of mastitis - SRB	Bendixen (1988)
	RR = 2.3	without previous occurrence of mastitis - SLB	Bendixen (1988)
	RR = 2.1	with previous occurrence of mastitis - SLB	Bendixen (1988)
	RR = 2.7		Milian-Suazo et al. (1988)
Ketosis	NS		Cobo-Abreu et al. (1979b)
	(-)	occurrence in the previous lactation	Martin et al. (1982)
	(-)	culling before 150 d pp	Dohoo and Martin (1984c)
	NS		Bigras-Poulin (1985)
	OR = 0.8		Gröhn and Saloniemi (1986)
	NS	with or without previous parturient paresis - SRB	Bendixen (1988)
	NS	with or without previous parturient paresis - SLB	Bendixen (1988)
	RR = 1.2		Milian-Suazo et al. (1988)
	NS	primiparous	Oltenacu et al. (1990)
	OR = 0.8	primiparous	Oltenacu et al. (1990)
Locomotor disorders	NS		Cobo-Abreu et al. (1979b)
	(-)	occurrence in the previous lactation	Martin et al. (1982)
	RR = 19.5	culling before 150 d pp	Dohoo and Martin (1984c)
	NS		Bigras-Poulin (1985)
	RR = 1.7		Milian-Suazo et al. (1988)

[1]RR: relative risk; OR: odds ratio; (+): positive association (discriminant analysis); (-): negative association (discriminant analysis); NS: no significant association; [2]d: days; pp: post-partum; SRB: Swedish Red and White breed; SLB: Swedish Friesian breed.

A few other reproductive disorders (abortion, stillbirth) have been studied in relation with culling (Dohoo and Martin, 1984c; Bigras-Poulin, 1985; Milian-Suazo et al., 1988; Oltenacu et al., 1990).

The inclusion of reproductive performance of a cow when investigating the risk of culling could lead to either deletion of the direct effect of reproductive disorders on risk of culling or inclusion of an additional indirect effect. Therefore, metritis and cystic ovaries were indirect risk factors through the mediation of an increased number of services. Decreased fertility in cows with cystic ovaries was also found in several studies (Shanks et al., 1979; Erb et al., 1981a, 1981b; Dohoo and Martin, 1984b). Moreover, dystocia and retained placenta could be an indirect risk factor for culling through the occurrence of other reproductive diseases and poor breeding performances (Erb et al., 1985).

Mastitis

An increased risk of culling in cows which have experienced mastitis is a classical finding, regardless of the differences between breeds, study periods and countries concerned (Cobo-Abreu et al., 1979b; Dohoo and Martin, 1984c; Bigras-Poulin, 1985; Erb et al., 1985; Gröhn and Saloniemi 1986; Bendixen, 1988; Milian-Suazo et al., 1988; Oltenacu et al., 1990). The very high relative risk of culling within 150 days post-partum in relation to mastitis requiring systemic therapy was noteworthy (Dohoo and Martin, 1984c).

High milk somatic cell count, was positively associated with both the risk of being sold for dairy purposes and that of being culled after 150 days post-partum (Dohoo and Martin, 1984c).

Teat problems

Few authors investigated these health disorders as possible risk factors. The occurrence of "teat" (Milian-Suazo et al., 1988), "teat injury" (Dohoo and Martin, 1984c), "tramped teat" (Bendixen, 1988) was associated with an increased risk of culling. This risk was unrelated to the previous occurrence of mastitis in the lactation (Bendixen, 1988). By contrast, Bigras-Poulin (1985) found no association between "teat injury" and culling.

Ketosis

There was no obvious conclusion on the effect of ketosis as a risk factor for culling. The studies reported contradictory results. The negative association between ketosis and culling (Dohoo and Martin, 1984c, Gröhn and Saloniemi, 1986, Oltenacu et al., 1990) could be related to a positive association between ketosis and milk yield level (Dohoo and Martin, 1984c).

Locomotor disorders

Major discrepancies were found between results in both the trend and the strength of the relationship. These may be due to differences from one study to another in types of locomotor disorders recorded in the field. The broad term "foot problems" was reported in all studies, which, consequently, does not provide any precise definition of the actual locomotor disorders taken into account. The risk of culling may vary between occurrences of either acute or chronic lameness. It may also depend on lameness diagnosis, and farmers' ability to detect it. Many foot problems stay on a subclinical level and perhaps do not play an important role in the culling decision of farmers. Only 2 % of the dairy cows are disposed because of feet and leg disorders (Beynon and Howe, 1974; Thiel, 1980; Dijkhuizen, 1983).

A positive association between lameness and culling was found by Dohoo and Martin (1984c) and Milian-Suazo et al. (1988). Collick et al. (1989), in a case-control study reported a higher culling rate for lame cows, without controlling for other diseases. Lameness may be an indirect risk factor for culling mediated through poorer breeding performances (Lucey et al., 1986; Collick et al., 1989).

Other health disorders

Cows which have experienced pneumonia had a greater risk of culling (Cobo-Abreu et al., 1979b; Dohoo and Martin, 1984c). Abomasal displacement was not a risk factor for culling (Cobo-Abreu et al., 1979b; Martin et al., 1982; Dohoo and Martin, 1984c). The miscellaneous digestive tract disorders were significantly associated with culling after 150 days post-partum (Dohoo and Martin, 1984c).

CONCLUSIONS AND AREAS FOR FUTURE RESEARCH

Studying relationships between health problems and culling requires field surveys which are expensive and time-consuming. The willingness of a sufficient number of farmers to record daily occurrences of diseases and cullings is also needed. This may explain why diseases as possible risk factors for culling are poorly documented. General trends can be found for certain particular health disorders (dystocia, parturient paresis, mastitis), whereas discrepancies are found for many others. It is noteworthy that all the results have to be interpreted in relation to each specific study design and population involved (years of the study period, production systems, breeds).

Furthermore, most of the studies to date are only focused on the relationships between a particular disease (or group of diseases) and culling, and include a limited number of other parameters possibly influencing culling (Table 2). Therefore, continued research is needed. Considering the previous publications, several important areas are worthy of interest. The order of listed items below is not intended to reflect their relative importance.

1) Diseases in one lactation could be systematically estimated as potential risk factors for culling in the following lactation.
2) The suitability of assessment of a general derived criterion as a "cow health status" (instead of a criterion based on a particular disease) as a "risk factor" should be investigated. No author studied such a synthetic "cow health status" criterion as an hypothetic risk factor for culling. One may assume that culling decisions related to health disorders depend not only on the type of diseases the cow had experienced but also on the number of occurrences and of the associations between diseases.
3) Diseases as indirect risk factors through low milk production and/or poor breeding performance could be more extensively investigated. Certain reproductive disorders such as metritis, retained placenta and cystic ovaries seemed to be indirect risk factors for culling through the mediation of poor breeding performance. In contrast, breeding performance variables were mostly used as "outcome" variables for reproductive disorders.
4) The introduction of some relevant herd factors as possible main effects or confounders may be interesting. One may assume that the level of incidence of

the diseases in a herd could lead to anticipated cullings related to health disorders. Furthermore, culling decisions are highly dependent on the whole environment of the herd. Within the European milk quotas context, culling policies are greatly influenced not only by technical but also by economic considerations and may vary between herds. Therefore, inclusion of some descriptive criterions of the herd could be relevant. Such parameters may relate to, for instance, the production system, the herd structure, the herd management, the type of replacement and culling policies, the herd health status and reproductive performances and the sociopsychological profile of the owner.

The studies mentioned in this review provide relevant information on the role of health disorders with respect to culling decisions. This information has been taken into account in models for culling and replacement decision support. Culling decisions are often based on economic considerations. A farmer will cull a cow when he expects a higher revenue by replacing the cow than by keeping her in the herd. Several studies investigating culling and replacement policies at the herd level have included the involuntary disposals as an economic component. They showed that the level of involuntary cullings greatly influenced the annual income per cow per year (Allaire and Cunningham, 1980; Van Arendonk, 1985; Dijkhuizen et al., 1986; Rogers et al., 1988). Therefore, studies investigating the influence of diseases on culling could provide relevant information to be included in further models for culling decision support. Because of the discrepancies between results depending on the production systems studied, a complete correspondance is compulsory between the origins of field data and the production system accounted for in the culling decision models.

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RESUME

Associations entre troubles de santé et réforme chez la vache laitière : revue bibliographique

Les relations entre les troubles de santé et la réforme des vaches dans les troupeaux laitiers sont passées en revue, en mettant à la fois l'accent sur les résultats et leurs facteurs de variation. Des tableaux permettent une étude comparative des protocoles mis en oeuvre et des résultats obtenus dans les travaux antérieurs.

Les différences entre populations d'étude sont décrites. Les définitions des troubles de santé pris en compte et leurs modalités d'observation sont discutées. D'autres caractéristiques individuelles des vaches (âge, niveau de production laitière, performances de reproduction) sont généralement prises en compte dans les analyses, tandis que l'effet "troupeau" sur le risque individuel de réforme est rarement analysé. Les méthodes statistiques employées en vue de l'analyse des troubles de santé en tant que facteurs de risque de la réforme sont résumées.

Certaines affections (dystocie, mammite) augmentent le risque de réforme, quel que soit le système de production étudié. Cependant, pour d'autres troubles de santé (coma vitulaire, métrite, kystes ovariens, rétention placentaire, boiteries), des résultats contradictoires sont rapportés. Ces disparités résultent, soit de différences réelles dans les systèmes de production étudiés, soit de différences d'ordre méthodologique.

L'intérêt d'études complémentaires, évaluant tout particulièrement l'effet "troupeau" sur le risque de réforme individuel, est souligné.

ZUSAMMENFASSUNG

Beziehungen zwischen Gesundheitstörungen und Abgänge bei Milchkühen : Literaturübersicht

Die Verbindungen zwischen Krankenheiten und Abgänge der Milkühe sind angesehen, und die Resultate mit ihren Variationfaktoren diskutiert. Die Tabellen vergleichen die Protokolle und die Daten der vorherigen Studien.

Der Verfasser beschreibt die Unterschiede in die ausgewählte Populationen. Die Definitionen der Gesundheitstörungen, die hier umgefasst sind, werden diskutiert ; sowie die Beobachtungsmethoden, die benutzt sind. Andere individuelle Kriterien der Kühe (Alter, Milchproduktion, Fortpflanzungleistung) sind im allgemeinen analysiert, im Gegenteil ist der "Herdeffekt" auf dem individuellen Abgangrisiko selten betrachtet. Die statistiche Methoden, die für diese Beziehungen verwendet wurden, sind kurzgefasst.

Einige Gesundheitstörungen (Schwergeburt, Mastitis) vergrössern den Abgangrisiko, und dieser ist von dem Produktionsystem unabhängig. Trotzdem, für andere Krankheiten (Milchfieber, Gebärmuttererkrankungen, Ovarzysten, Nachgeburtverhaltung, Lähmungen), gibt die Literatur widersprechende Resultate. Diese Unähnlichkeiten stammen wahrscheinlich entweder von wirklichen Unterscheiden in den Produktionsystemen, oder von methodologischen Urkunden aus. Weiterführende Studien, die besonders den "Herdeffekt" auf dem individuellen Abgangrisiko betreffen würden, sollen eine wichtige Interesse haben.

CHAPTER 2

ASSOCIATIONS BETWEEN HEALTH DISORDERS OF FRENCH DAIRY COWS AND EARLY AND LATE CULLING WITHIN THE LACTATION

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ASSOCIATIONS BETWEEN HEALTH DISORDERS OF FRENCH DAIRY COWS AND EARLY AND LATE CULLING WITHIN THE LACTATION

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ABSTRACT

Data from an observational study, carried out during a four and a half year period (from 1986 to 1990), were used to quantify the effects of health disorders on the risk of culling. The study population consisted of 47 commercial Holstein dairy herds from western France, comprising 4123 cows. Logistic regression was used to assess the relationships between health disorders and early and late culling. 14 main health disorders with clinical signs and 1 subclinical disease were studied: abortion, periparturient accident, calving provided with assistance, digestive disorders, ketosis, locomotor disorders, mastitis, metritis, milk fever, cystic ovaries, respiratory disorders, retained placenta, teat injuries, non traumatic udder disorders, status with respect to milk somatic cell count. Adjustments were made for year, month of calving, parity, breeding value for milk, best of the two first milk production records and reproductive performance. The possible effects of interactions among variables were also studied. The herd effect was taken into account using random effect models. Non traumatic udder disorders, teat injuries, milk fever and the occurrence of both ketosis and assistance at calving were significantly associated with an increased risk of being early culled (odds ratios (OR) ranging from 1.6 to 10.3). Early and late abortion, late metritis, poor reproductive performance, retained placenta, non traumatic udder disorders within 45 days post-partum and mastitis occurring in the first three months of the lactation were positively associated with a late culling (OR ranging from 1.2 to 6.6). Cows with lower breeding value for milk and higher parities were high risk groups for culling. A lower level of milk production and occurrence of both reproductive disorders and poor reproductive performance were risk factors for late culling.

Key words: dairy cow, culling, disease, epidemiological risk factors

INTRODUCTION

With milk-production quotas, the reduction of the production costs has been put forward as a way to maintain profitability of dairy farms. Thus, more attention is now paid to health management in order to minimize losses due to health disorders. Losses caused by health disorders in dairy herds were estimated at Dfl. 400 per present cow per year in the Netherlands (Dijkhuizen, 1983).

The contribution of cullings to disease-related losses is relatively large. Sol et al. (1984) estimated that the loss due to a forced replacement of a cow varied from Dfl. 460 to 1270 depending on the culling reason.

From some studies concerning health disorders as risk factors for culling (Cobo-Abreu et al., 1979; Martin et al., 1982; Dohoo and Martin, 1984; Oltenacu et al., 1984; Bigras-Poulin, 1985; Erb et al., 1985; Gröhn et al., 1986; Bendixen, 1988; Milian-Suazo et al., 1989; Oltenacu et al., 1990), it can be pointed out that certain health disorders (dystocia, mastitis) increase the risk of culling regardless of the production systems considered. However, for other health disorders (milk fever, metritis, cystic ovaries, retained placenta, locomotor disorders), contradictory results are reported.

All studies investigating associations between diseases and culling, except one (Dohoo and Martin, 1984), were performed without considering the moment of culling within the lactation. Farmers' culling decision-making process is probably not identical for cows culled early in lactation and for cows culled later. Consequently, the effects of diseases on culling may also show variations.

Therefore, recent knowledge on the effects of health disorders as risk factors for early and late culling is needed in order to improve farmers' management, and more specifically, to provide information useful to calculate the economic impact of diseases.

The objective of this study was to assess and to quantify the relationships between health disorders of dairy cows and culling depending on whether the cows were culled early or late in lactation.

MATERIALS AND METHODS

Study population

A prospective longitudinal survey was conducted in 47 commercial Holstein herds situated in western France. Data were collected between 1 February 1986 and 30 June 1990. Quotas in milk production were in effect. To participate in the study, herds had to be of the Holstein breed, enrolled in a milk production recording program and cows had to be bred primarily by artificial insemination. The herd selection was also based on the owner's willingness to cooperate during the duration of the study. Table 1 gives some average technical characteristics of the concerned herds, calculated on a three year period basis (1 February 1987 to 31 January 1990). Culling and replacement rates were respectively the number of cullings and the number of calvings of heifers divided by the average number of cows present.

Table 1. Main characteristics of the 47 dairy herds (calculated on a three-year period, from 02/01/1987 to 01/31/1990)

Variable	Mean	Sd	Minimum	Maximum
Average herd milk yield (kg/cow/year)	7103	571	6044	8641
Average number of present cows per herd	42	12.3	20	78
Culling rate (/present cows) (%)	32.7	7.1	21.4	56.5
Replacement rate (/present cows) (%)	29.3	5.9	18.2	43.1

Data collection and validation

Data concerning the disease occurrences were obtained from routinely collected records of both the farmers and the veterinarians. A glossary presenting the general rules of data recording and defining the symptoms was provided to the farmers. Each herd was visited approximately every 6 weeks by a trained technician, who collected individual demographic data concerning new calvings and cullings, and disease occurrences recorded since the last visit. The monthly milk production records were obtained directly from the milk production recording agency on magnetic computer tape. A database was designed for the storage of the information (Lescourret et al., 1993).

The data included all lactations that started between 1 February 1986 and 31

December 1989 and ended (by a culling or a new calving) before 1 July 1990.

Symptoms initially described by farmers and/or veterinarians with a glossary were recoded to a diagnosis by a single researcher. Data editing was done during and after storage, by checking for impossible values. The interval between calving and occurrence of disease was paid extra attention, especially for periparturient events like dystocia and milk fever. Dystocia had to occur on the day of calving, milk fever within an interval [-6,+10] days around calving. The coherence of demographic data (age at calving related to parity, calving interval, days in milk at culling), reproductive performance related data (days to first artificial insemination, days open) was checked and typing errors resulting in suspicious values of these calculated intervals were corrected.

Definition of outcome variable

The unit of observation was the cow-lactation. Lactations ended either by a culling or a new calving. Lactations ending by death (0.8 %) were excluded.

Culling can occur either very early or later within the lactation (Figure 1). Our hypothesis was that the culling decision for cows culled very early within the lactation probably was not made on the same basis as for cows culled later in the lactation.

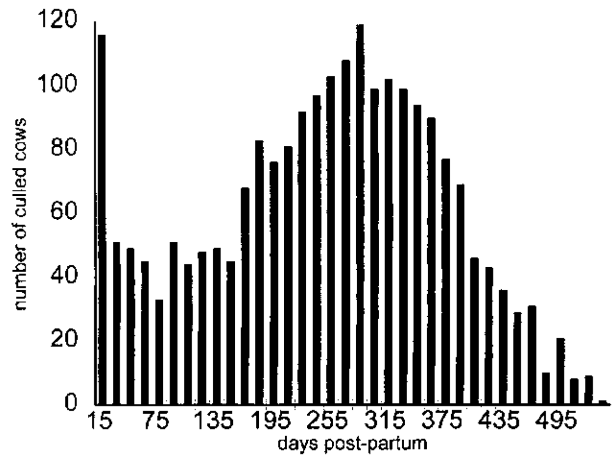

Figure 1. Distribution of culled dairy cows by days post-partum (15-day intervals) in western France (1986 - 1990)

A culling was defined as either an early or a late culling. This classification was thought to be relevant because of two aspects:

1. the fact that the culling decision is largely based on milk production;
2. the fact that a delay may occur between the culling decision and the actual culling.

Cows culled very early in a given lactation may not achieve a first milk production record. When considering milk production as possible risk factor for culling, most of the early culled cows would have been excluded systematically because of missing milk-production records. Considering all cows culled between calving and a given day post-partum, the proportion of missing milk-production records decreased when the interval between calving and culling increased, and strongly dropped at day 45 post-partum. Therefore, all animals culled before day 45 post-partum were defined as being early culled.

A time gap might exist between the decision to cull a cow and the actual moment of culling. In some cases, this can be derived from the number of milk records of the culled cows, because the farmer will withdraw some cows from the milk recording as soon as it is decided to cull them. Thus, many cows showing only one milk record could be classified as having early decisions to be culled, whatever their actual time of culling within the lactation. Therefore, lactations ending by culling after day 45 post-partum but with only one milk record which was achieved before day 30 post-partum were also designated as early culling. The 30 day post-partum threshold was a compromise, in order to limit the number of misclassified cow-lactations. We assumed that day-45 post-partum constituted the higher delay for decision-making of early-culled cows. Given the fact that the average interval between two milk records was about 30 days, the threshold of 30 days post-partum constituted the upper limit post-partum for the achievement of the first milk record, with the assumption that the culling decision was made within the first half of the interval between two milk production records.

All other cullings were considered as late cullings.

Table 2 shows the overlap between early and late cullings, with respect to days post-partum at culling. Seventy-eight per cent of early cullings corresponded to actual cullings within 45 days post-partum. Twenty-five per cent of cow-lactations ending by a culling and with only one milk record were classified as late culling in our dataset, because of an unique milk record after 30 days post-partum.

Table 2. Distribution parameters of days post-partum at culling for early and late culled cows

Variable	Minimum	25% quartile	Median	75% quartile	Maximum
Days at early culling	0	7	23	41	241
Days at late culling	50	213	285	354	1072

Two separate analyses were performed. In order to investigate diseases as risk factors for early culling (analysis 1), the early cullings were compared to a group consisting of all not culled cows and late cullings. In this analysis, milk yield was not included in the models. In order to investigate diseases as risk factors for late culling (analysis 2), the late cullings were compared to a group including cow-lactations ending by a new calving; milk yield was included in the models.

Definition of explanatory variables

Table 3 lists the health disorders and the reproductive and milk production parameters used in analyses 1 and 2.

Only common health disorders were investigated as possible risk factors for culling. Some health disorders, e.g. poisonings, eye-diseases, urinary disorders, left abomasal displacement, acidosis, salmonellosis, respiratory strongylosis, skin-diseases showed a low incidence (<0.4%). Other symptoms dealing with general conditions (fever, milk production drop) could not be related directly to a specific health disorder. These observations were therefore not taken into account. The remaining initially coded diagnoses were gathered in 14 groups of health disorders (Table 3). All diseases were considered as soon as clinical signs were present. The subdivision of several general health disorders into categories was intended to reflect either the distribution within stage of lactation of the concerned diseases, and/or was based on biological justifications. A first threshold was determined at 45 days post-partum for mastitis, teat injuries and non traumatic udder disorders in order to consider the occurrence of these diseases before and after the peak of lactation. Furthermore, this approach made it possible to study in part the effect of recurrence of the same health disorder in the same lactation. The minimum time between two occurrences of one disease in order to be considered as separate episodes was 3 months. Furthermore, for mastitis and locomotor disorders, two episodes were considered as separate, whatever the time interval between them, if they did not affect the same udder quarter or leg respectively.

The milk somatic cell count status (SCC), which was information available to the farmers, was defined according to Serieys (1985). For each monthly milk record, the milk somatic cell count value was compared to two thresholds: 300 000 and 800 000 cells/ml respectively. Then, for each cow-lactation, SCC was evaluated by accounting for all milk cell counts available throughout the lactation. Three categories were created. The first category included the cow-lactations with all her milk somatic cell count records below 300 000 cells/ml throughout her lactation (SCC1). The second category included the cow-lactations with (1) at least one record between 300 000 and 800 000 cells/ml and the others below 300 000 cells/ml or (2) only one record higher than 800 000 cells/ml and the others below 300 000 cells/ml (SCC2). The third category comprised the remaining cow-lactations (SCC3).

Infertility was measured using a synthetic indicator (REPRO) based on the status: cow with or without reproductive failure at 110 days post-partum. For cows culled before 110 days post-partum, the reproductive status was defined at culling and assigned to the variable REPRO. First, REPRO was based on the interval between calving and the last registered artificial insemination (ICLAI), for each lactation of cows served by artificial insemination. If ICLAI was larger than 110 days, then the cow was assigned as having reproductive failure at 110 days post-partum. Second, reproductive failure was defined to be present in cows that were not inseminated and culled after 110 days post-partum, or in cows that were not inseminated and culled for a reason related to reproductive ability. In all other cases, the cow was assumed to be free of reproductive failure at 110 days post-partum.

All diseases, REPRO and culling were coded as 0,1 (no, yes) dichotomous variables. The year of calving and the month of calving were explicitly considered. Parity was treated as a discrete variable with seven classes : 1, 2, 3, 4, 5, 6, >6. The breeding value for milk of each cow included in the dataset (BVM) was evaluated according to Bonaiti et al. (1990), and corresponded to its estimation in February 1992. To evaluate milk production at the beginning of the lactation, the best of the two first milk yield records in kg (START) was taken into account and was included in the analyses as a continuous variable.

Table 3. Description of disease, reproductive performance and milk production variables, distribution of cow-lactations, and percentage of culled cow-lactations for each level of variables taken into account in the analysis 1 (early culling) and in the analysis 2 (late culling)

Abbreviation/Definition of variables[a]		Level	Cow-lactations			
			Analysis 1		Analysis 2	
			n[b]	%[c]	n[b]	%[c]
Reproductive performance and milk production variables						
REPRO[1]	reproductive failure at 110 days pp[2]	yes	-	-	2534	44.2
		no	-	-	3791	14.4
START[1]	best of the two first milk records (kg of milk)					
BVM	breeding value for milk (kg), estimated on	missing	182	1.7	64	50.0
	February 1992	<0	719	1.0	552	41.1
		0 - 400	1630	0.8	1451	32.7
		400 - 800	2275	0.8	2091	26.7
		800 - 1200	1561	0.4	1494	19.3
		>1200	696	0.1	673	12.3
Disease variables[3]						
ABO1[1]	abortion from 100 to 180 days of gestation	yes	-	-	55	67.3
		no	-	-	6270	25.9
ABO2[1]	abortion at more than 180 days of gestation	yes	-	-	67	44.8
		no	-	-	6258	26.1
ACC	accident, trauma, haemorrhage of genital tractus,	yes	121	6.6	102	38.2
	embryotomy, caesarean section, leg paralysis diagnosed at 10 days or less pp	no	6942	3.8	6223	26.1
ASSIST	calving provided with assistance	yes	597	5.7	520	31.2
		no	6466	3.7	5805	25.9
DIG[1]	miscelleanous digestive disorders	yes	-	-	283	28.9
		no	-	-	6042	26.2
KETO	ketosis or loss of appetite without	yes	223	8.1	184	32.6
	any concurrent health disorders within a [-3,+3] days interval, diagnosed at 45 days or less pp	no	6840	3.7	6141	26.1
LOC[1]	foot and leg disorders	yes	-	-	901	28.9
		no	-	-	5424	25.9
MAS1	mastitis diagnosed at 45 days or less pp	yes	845	4.4	715	34.8
		no	6218	3.8	5610	25.2
MAS2[1]	mastitis diagnosed from 46 to 90 days pp	yes	-	-	328	33.8
		no	-	-	5997	25.9
MAS3[1]	mastitis diagnosed from 91 to 180 days pp yes	-	-	410	33.7	
		no	-	-	5915	25.8
MAS4[1]	mastitis diagnosed from 181 to 270 days pp yes	-	-	259	30.9	
		no	-	-	6066	26.1
MAS5[1]	mastitis diagnosed at 271 days or more pp yes	-	-	105	24.8	
	(diagnoses within the dry period were excluded)	no	-	-	6220	26.3

[a] for definition of REPRO and SCC, see text.
[b] n: number of cow-lactations;
[c] %: percentage of culled cow-lactations.
[1] not used in analysis 1.
[2] pp: post-partum
[3] for each disease variable, the cow was positive when the event occurred at least once.

Abbreviation/Definition of variables[a]		Level	Cow-lactations			
			Analysis 1		Analysis 2	
			n[b]	%[c]	n[b]	%[c]
Disease variables[3]						
MET1	vaginitis, vulvitis, vulvo-vaginitis, endometritis,	yes	545	0.7	506	30.0
	vaginal discharge, metritis, pyometritis	no	6518	4.1	5819	25.9
	diagnosed at 21 days or less pp[2]					
MET2[1]	vaginitis, vulvitis, vulvo-vaginitis, endometritis,	yes	-	-	433	28.9
	vaginal discharge, metritis, pyometritis	no	-	-	5892	26.1
	diagnosed from 22 to 49 days pp					
MET3[1]	vaginitis, vulvitis, vulvo-vaginitis, endometritis,	yes	-	-	412	38.4
	vaginal discharge, metritis, pyometritis	no	-	-	5913	25.5
	diagnosed at 50 days or more pp					
MF	milk fever	yes	564	6.9	488	35.3
		no	6499	3.6	5837	25.5
OVA1[1]	cystic ovaries diagnosed from 46 to 90 days pp	yes	-	-	156	26.9
		no	-	-	6169	26.3
OVA2[1]	cystic ovaries diagnosed from 91 to 150 days pp	yes	-	-	89	33.7
		no	-	-	6236	26.2
OVA3[1]	cystic ovaries diagnosed at 151 days or more pp	yes	-	-	40	40.0
		no	-	-	6285	26.2
RES1[1]	respiratory disorders	yes	-	-	191	23.6
	diagnosed at 150 days or less pp	no	-	-	6134	26.4
RES2[1]	respiratory disorders	yes	-	-	121	21.5
	diagnosed at 151 days or more pp	no	-	-	6204	26.4
RP	retained placenta (>12 hours)	yes	767	3.4	680	35.7
		no	6296	3.9	5645	25.2
SCC[1]	milk somatic cell count status	SCC1	-	-	3232	23.1
		SCC2	-	-	1869	26.0
		SCC3	-	-	1224	35.4
TEA1	teat injuries diagnosed at 45 days or less pp	yes	52	19.7	32	37.5
		no	7011	3.7	6293	26.2
TEA2[1]	teat injuries diagnosed at 46 days or more pp	yes	-	-	66	36.4
		no	-	-	6259	26.2
UDD1	non traumatic udder disorders diagnosed	yes	176	9.7	134	38.8
	at 45 days or less pp (mastitis excluded)	no	6887	3.7	6191	26.0
UDD2[1]	non traumatic udder disorders diagnosed	yes	-	-	74	25.7
	at 46 days or more pp (mastitis excluded)	no	-	-	6251	26.3

[a] for definition of REPRO and SCC, see text.
[b] n: number of cow-lactations.
[c] %: percentage of culled cow-lactations.
[1] not used in analysis 1.
[2] pp: post-partum.
[3] for each disease variable, the cow was positive when the event occurred at least once.

Statistics

A 4-stage procedure was used to assess the relationship between diseases and culling. The first three stages were carried out using the LOGISTIC Procedure of SAS (SAS Institute Inc., 1989), according to the method described by Hosmer and Lemeshow (1989).

In the first stage, an univariate analysis was done to relate culling to each health disorder plus the reproductive indicator (REPRO) for analysis 2. Only factors associated (likelihood ratio chi-square test, $P < 0.25$) with culling were offered to the multivariate models.

The second stage involved a multiple logistic regression model. It included all risk factors which passed the first screening. Dummy variables for year, parity, month of calving, breeding value for milk (BVM) for both analysis 1 and 2, and best of the two first milk production records (START) for analysis 2, were forced into all models, whatever their level of contribution. To investigate the contribution of diseases and reproductive status to the models, Wald's criterion, which tests the null hypothesis (H_O: β=0), was used to assess the significance of each term in the model (Wald, 1943). The variable with the highest P was removed and the logistic regression was rerun without this term. The deviance difference is a likelihood ratio statistic and was used to assess the goodness-of-fit of the models (McCullagh and Nelder, 1989). The process of deleting, refitting and verifying was continued until a model was obtained with all diseases significant at $P < 0.10$ (model A).

In the third stage, two-way interaction terms among the variables were considered. The diseases were hypothesized to interact between each other, and also with reproductive status, parity, and milk production parameters. Each possible interaction was tested by its addition alone to model A and only interaction terms significantly related to culling ($P < 0.25$) were kept after this screening. All the significant interaction terms then were added simultaneously to model A to obtain model B. The interaction term with the highest P value of the Wald's test was removed and the logistic procedure was rerun without this term. Again, the deviance difference was used to assess the goodness-of-fit of the models. The process was continued until a final model was obtained with significant ($P < 0.10$) interactions (model C). At this stage, variables involved in interaction terms may become non significant ($P \geq 0.10$) as main effects. However, the concerned variables were kept in the hierarchical final model.

In the fourth stage, a random effect logistic model with herd as main plot was used to account for the fact that cows within herds might not be independent (Curtis et al., 1993). Logistic binomial regression assumes that the random perturbation in the binomial proportion follows a standardized binomial distribution and was run as a special case of the method for ordinal data described by Jansen (Jansen, 1990). The number of quadrature nodes was set to 5. Computations were carried out using a FORTRAN program developed by Jansen. The general effect of taking between-herd variation into account is that the standard errors of the regression coefficients are larger compared with ordinary logistic regression. Both Wald's criterion and the likelihood ratio chi-square statistic for testing the significance of deleting a variable to the model can be too large (Goelema et al., 1991, Curtis et al., 1993). Thus, the null hypothesis will be rejected less often. The model C was therefore rerun in order to adjust the partial regression coefficients and their standard errors. A backward procedure based on the likelihood ratio chi-square statistic was performed until a hierarchical final model was obtained with significant interactions ($P < 0.10$).

To provide epidemiologically interpretable effects of variables involved in the interaction terms, (e. g. disease A, disease B, interaction term A x B), odds ratios were calculated considering presence of both A and B, relatively to absence of both A and B. In addition, odds ratios were calculated for the direct main effects of variables involved in interaction terms, given that the value of other variables involved in interaction terms was equal to zero, i.e. presence of A, absence of B, relatively to absence of both A and B. For categorical variables, odds ratios were calculated relative to the reference category.

RESULTS

Health disorders as risk factors for early culling (analysis 1)

7063 lactations from 3671 cows were considered for the statistical analysis. The data set showed 270 early cullings and 6793 cow-lactations without early culling.

An increased breeding value for milk was associated negatively with the risk of being culled, following an apparent progressive trend (Table 4).

Only 3 health disorders (MF, TEA1, UDD1) were positively related to culling as direct main effects, while MET1 was associated negatively with it.

A cow having experienced both an assisted calving (ASSIST) and ketosis (KETO) had a 10.3 times higher risk of being culled than a cow without these two events. Furthermore, a cow in parity 5 having experienced ketosis had a 17.3 times higher risk of being culled than a primiparous cow without that disease. 3 health disorders (ACC, MAS1, RP) were not significantly related to culling either as main effects or as interaction terms.

Table 4. Variables in the final logistic regression model for risk factors for early culling of French dairy cows (7063 lactations) and their relation to culling. Only variables or combinations of variables significantly related to culling (P < 0.10) are reported.

Variable[1]	Percentage of cow-lactations (%)	Odds ratio	95% CI
Parity			
parity 1	27.1	1.0	-
parity 2	21.5	0.6	0.4 - 0.9
parity 3	17.1	1.2[NS]	0.7 - 1.8
parity 4	12.6	1.1[NS]	0.7 - 1.8
parity 5	9.3	1.0[NS]	0.6 - 1.7
parity 6	6.4	1.2[NS]	0.7 - 2.1
parity 7 and over	6.0	2.1	1.3 - 3.4
Breeding value for milk (BVM) (kg)			
missing	2.6	24.0	14.4 -40.0
< 0	10.2	6.2	4.1 - 9.3
0 - 400	23.1	1.7	1.1 - 2.5
400 - 800	32.2	1.0	-
800 - 1200	22.0	0.7[NS]	0.4 - 1.1
> 1200	9.9	0.5	0.3 - 0.9*
Metritis (MET1)	7.7	0.3	0.1 - 0.6
Milk fever (MF)	8.0	1.6	1.1 - 2.5
Teat injuries (TEA1)	0.7	6.0	2.6 -13.6
Non traumatic udder disorders (UDD1)	2.5	2.6	1.4 - 4.8
Ketosis (KETO) and ASSIST	0.2	10.3[2]	2.0 -52.1
Ketosis (KETO) and parity 5	0.3	17.3	5.5 -54.3

Deviance difference of model=493.6 with 38 d.f. (P < 0.001); random-effects coefficient: s=0.61; SE(s)=0.11.
[NS] non significantly related to culling (P = 0.10).
* 90% CI (confidence interval).
[1] In addition, year of calving (reference: 1987), month of calving (reference: October) were included in the model.
[2] Reference for combination of health disorders was absence of health disorders involved in the combination.

Health disorders as risk factors for late culling (analysis 2)

6325 lactations from 3265 cows were considered in the statistical analysis. 468 observations had been deleted because of missing START data. Cow-lactations ending by an early culling had also been deleted. This data set consisted of 1663 late cullings and 4662 cow-lactations ending by a new calving.

An increased breeding value for milk was associated negatively with culling, following an apparent progressive trend (Table 5). As in analysis 1, a missing breeding value for milk was strongly associated with a higher risk of being culled. Furthermore, each increase of 5 kilograms in the value of START implied a 0.6-fold protection from culling.

Table 5. Variables and variable categories in the final logistic regression model for risk factors for late culling of French dairy cows (6325 lactations) and their relation to culling. Only variables or combinations of variables significantly related to culling (P < 0.10) are reported.

Variable[1]	Percentage of cow-lactations (%)	Odds ratio	95% CI
Parity			
parity 1	27.1	1.0	-
parity 7 and over	5.5	5.1	1.1 -25.1*
Breeding value for milk (BVM) (kg)			
missing	1.0	3.2	1.7 - 5.9
< 0	8.7	1.8	1.4 - 2.3
0 - 400	22.9	1.4	1.2 - 1.7
400 - 800	33.1	1.0	-
800 - 1200	23.6	0.7	0.6 - 0.8
> 1200	10.6	0.4	0.3 - 0.6
Best of the two first milk records (START) (kg)	-	0.6[2]	0.5 - 0.7
Abortion (ABO1)	0.9	75.8[4]	9.3 - 621
Abortion (ABO1) and REPRO	0.7	17.4[3]	7.7 -39.4
Abortion (ABO2)	1.1	6.2[4]	3.2 -12.1
Abortion (ABO2) and REPRO	0.4	9.6[3]	3.5 -26.2
Accident (ACC) and REPRO	0.9	18.2[3]	9.1 -36.3
Mastitis (MAS1)	11.3	1.5	1.3 - 1.9
Mastitis (MAS2)	5.2	1.5	1.2 - 2.1
Mastitis (MAS3) and calving in June	0.4	7.3	2.6 -21.0
Metritis (MET3)	6.5	2.3[4]	1.4 - 3.8
Metritis (MET3) and ASSIST	0.8	8.8[3]	4.1 -18.7
Metritis (MET3) and REPRO	4.8	6.7[3]	3.9 -11.4
Retained placenta (RP)	10.8	1.2	1.0 - 1.4*
Non traumatic udder disorders (UDD1)	2.1	2.1	1.3 - 3.2
REPRO	40.1	6.6[4]	4.0 -10.9
REPRO and parity 7 and more	2.8	80.3	10.9 - 591
Absence of REPRO and calving in October	6.8	1.0	-
REPRO and calving in September	3.6	4.6	3.5 - 6.0
REPRO and calving in November	3.7	5.2	3.9 - 6.8

Deviance difference of model=1605.5 with 77 d.f. (P < 0.001); random-effects coefficient: s=0.40; SE(s)=0.06.

* 90% CI (confidence interval).

[1] In addition, year of calving (reference: 1987), month of calving (reference: October) were included in the model. Interaction terms START x parity were not reported.

[2] unit: 5 kilograms increase of START (range: 7.2 - 55.1).

[3] Reference for combination of health disorders was absence of health disorders involved in the combination.

[4] Given that the value of other variables involved in interaction terms was equal to 0.

The direct main effect of ABO1 resulted in a 75.8 times higher risk of being culled, whereas a cow with both ABO1 and REPRO had a 17.4 times higher risk of being culled. ASSIST was not significantly related to culling as main effect, but a cow having experienced both assisted calving (ASSIST) and late metritis (MET3) had a 8.8 times higher risk of being culled than a cow without these two events. Diseases (ACC, MET3), parity and months of calving showed interactions with REPRO. The combination of ACC and REPRO resulted in a 18.2 times higher risk of being culled, relative to cows without these events. When a cow was characterized by both MET3 and REPRO, her risk of being culled was not higher than the risk for cows with REPRO. Cows calving in September or November and characterized by presumed reproductive failure at 110 days post-partum (REPRO) had a smaller risk of being culled than cows having calved in October with REPRO. Although the combination of MAS3 (mastitis between 90 and 180 days post-partum) and calving in June involved only 25 (0.4 %) observations, this combination was associated with a 7.3 times higher risk of being culled. The occurrence of MAS3 or calving in June did not increase significantly the risk of being culled as direct main effects. Owing to a significant interaction term between MET3 and MAS2 in the final hierarchical model, the combination of these variables corresponding to cows experiencing both metritis and mastitis after the peak of lactation had no significant effect on culling, although the occurrence of MET3 or MAS2 was significantly associated to an increased risk of culling.

DISCUSSION

This study was conducted in dairy herds with a higher performance level than that of average Holstein herds from western France. In the latter ones, the average milk yield per cow-lactation was about 6450 kg during the study period. The required willingness of farmers to cooperate during four years might have led to selection bias. Anyway a random selection was not deemed feasible for this type of project. Both the number of herds involved (47) and the study duration (4 years), in comparison to previous similar studies (Dohoo et al., 1983; Erb et al., 1985), will have contributed to a high precision of the results.

The fact that health disorders were recorded by farmers and veterinarians might have also contributed to variations between herds. However, possible variation between these observers was minimized by a pre-survey and an initial training of farmers, technicians and veterinarians concerning data collection and symptoms diagnoses, in addition to the prospective method used for data collection.

This study differs from other epidemiological studies dealing with associations between diseases and culling. Differences concern especially the economic context in which the study was carried out. The establishment of milk quotas in the EC in 1984 might have led to changes in culling decision-making. Furthermore, our strategy of analysis differs also from others, since random-effect models were used, and both time of culling and time of culling decision-making were taken into account. Also, the possible effect of recurrences of diseases on culling was partly investigated in the present study. Therefore, as already pointed out by Beaudeau et al. (1993), direct comparisons with other studies must be made with caution.

The use of random-effect multiple logistic regression was intended to account for the heterogeneity between herds with respect to the probability of culling. Because of the size of the dataset, implying huge computing time, the random-effect term was included in the logistic regression model only after assessment of the final fixed-effects with ordinary logistic regression. The inclusion of the random-effect term just after the univariate screening (second stage) could have led to removal of effects declared significant with ordinary logistic regression. However, such an analysis was not deemed feasible. A procedure close to ours was used by Wittum et al. (1990). Theoritically, a 2-level random-effect model should have been applied because cows are nested within herds and lactations are nested within cows. Although such a model has been described (Jansen, 1992), the excessive amount of computing time makes the use of it practically unsuitable when applying on datasets with many mainplots and sub-plots.

Multivariate regression methods imply the loss of all observations with at least one missing value for variables included in the model. The deletion of lactations with missing milk production and reproductive performance records could indeed lead to selection bias, particularly through the elimination of early-culled cows without any current milk-production record, or of culled cows without any services. In addition to biological and managerial justifications, these methodological constraints made it necessary to perform two separate analyses.

Two measures of productivity were used in this study: START and REPRO. START was intended to reflect the actual individual milk production potential. Wilmink (1987) reported that the last known test-day yield at 50 days post-partum could be relevantly used to predict 305-day milk yield. Reproductive performance in previous studies concerned days to first AI and number of services (Erb et al., 1985; Milian-Suazo et al., 1989). But the existence of these parameters is linked to the stage of lactation at culling. In analysis 2, both START and REPRO were independent on the culling status of the cow-lactation.

Culling was considered as a crude event in the present study, in contrary to Milian-Suazo et al. (1989) who investigated risk factors for reason-specific culling. Taking into account culling as a crude event was intended to focus on the culling decision-making process. No culling decision was made for cows which died. Consequently, lactations ending by a death were excluded. Only 9 cows were declared culled for notifiable diseases (enzootic bovine leucosis) by the farmers. The herds were involved in a national eradication programme of this disease during the study period.

The classification of certain diseases into categories was intended to assess the influence of time of occurrence of a disease on the risk for culling and the effect of possible recurrence of a disease within the lactation. Except for both MAS1 and MAS2 and late culling, the number of variables associated with culling for the same general health disorder never exceeded one. Thus, the stage of lactation at which a disease occurred appears to be a main criterion in the culling decision-making process. The recurrence of a same general health disorder within the lactation modified the risk of culling only through a simple multiplicative effect, since no interaction terms between variables attached to one disease were significant.

As a general rule, the interaction terms in the two final models involved a low percentage of observations each (less than 1%). Therefore, these interaction terms have to be interpreted with caution.

Parity and breeding value for milk were related to both early and late culling. The increased risk of culling by age was found also by Martin et al. (1982), Dohoo and Martin (1984), Bigras-Poulin (1985), and Gröhn et al. (1986). A possible explanation for parity 1 being at higher risk for early culling in comparison to parity 2 is that cows in first lactation are especially eliminated for "behaviour" and "type" culling reasons. The cows passing this selecting lactation are meant to be kept in the herd for a longer period. Only a few authors investigated breeding value for milk as risk factor for culling. Erb et al. (1985) found no direct effect of estimated transmitting ability of primiparous cows on culling, in contrary to Milian-Suazo et al. (1989) who reported, in a study investigating risk factors for reason-specific culling, that the breeding value for milk was associated negatively with culling for low milk production, feet and leg disorders and miscelleanous culling reasons.

When considering diseases as possible risk factors for early culling decision making, only a few of them were significantly related to culling. The culling decision-making process within 45 days post-partum was based principally on the occurrence of one severe health disorder, as supported by the nature of the diseases remaining in the final model. By contrast, the decision-making process for culling after 45 days post-partum appeared to be more complex.

4 periparturient events - accident (ACC), calving provided with assistance (ASSIST), milk fever (MF), retained placenta (RP) - were considered in both analyses. The finding that milk fever was positively associated with early culling is supported by Dohoo and Martin (1984) and Milian-Suazo et al. (1988) who both found a strong association with culling, especially for milk fever with the cow down. The latter paper reported a very short interval between occurrence of milk fever and culling. In contrast, milk fever was found negatively associated with culling by Bigras-Poulin (1985), and not associated by Martin et al. (1982), and Erb et al. (1985) who reported no direct effect. The positive effect of retained placenta on late culling was also found by Bigras-Poulin (1985), Bendixen (1988), Milian-Suazo et al. (1988), Oltenacu et al. (1990), in contrast to Martin et al. (1982), Dohoo and Martin (1984), Erb et al. (1985) who reported no significant direct effect. The adjustment for milk production could not explain such discrepancies, since similar trends are reported for the effects of both milk fever and retained placenta whether or not the milk production level was controlled. The possible effects of ACC on culling could be rather middle-term effects within the lactation and consequently not of influence on early-culling decision-making. This hypothesis is supported by the higher effect of the combination ACC and REPRO (in comparison to the direct main effect of REPRO) on late culling found in the present study and by findings of Mangurkar et al. (1984) and Barkema et al. (1992), who reported no difference in the interval between calving and first service, but a longer interval from first calving to conception for cows having experienced cesarean section and surgical dystocia respectively, in comparison to cows having a normal calving.

As a general rule, the udder-related diseases associated with culling were not the same for early and late culling. Teat injuries occurring before 45 days post-partum (TEA1) were positively associated to early but not to late culling, possibly because most of them resulted in impossibility of milking and then implied cullings within a short time. The positive effect of teat injuries on culling was also found by Dohoo and Martin (1984), Bendixen (1988) and Milian-Suazo et al. (1988). Mastitis before the peak of lactation (MAS1) was not related to early culling, possibly because the affected cows were treated for this disease in order to give them an opportunity to recover. However, an increased risk of culling for cows experiencing clinical mastitis is a classical finding (Cobo-Abreu et al., 1979; Dohoo and Martin, 1984; Bigras-Poulin, 1985; Gröhn et al., 1986; Bendixen, 1988; Milian-Suazo et al., 1988; Bendixen and Åstrand, 1989), which agrees with our results concerning the increased risk of late culling. Bendixen and Åstrand (1989) studied the influence of the stage of lactation at which mastitis occurred on culling and found that a cow experiencing mastitis after the third month post-partum had a higher risk of being culled than a cow without this disease, in contrast to our results. This discrepancy may be explained by differences in thresholds chosen to define mastitis within the lactation and by the adjustment for the somatic cell count status, possibly resulting in a decrease of the impact of this clinical disease. The somatic cell count status was not positively associated with late culling in the present study, in contrast to Dohoo and Martin (1984) (who reported that subclinical mastitis was the most important criterion in determining whether or not a cow was culled after 150 days post-partum). Such a discrepancy may be explained by differences in the definition of the milk somatic cell count status. In addition, during the study period, the French farmers usually were advised to give the cows with high milk somatic cell counts the opportunity to recover in a following lactation.

Dealing with reproductive disorders, a positive association between abortion and culling also was found by Bigras-Poulin (1985) and Milian-Suazo et al. (1988), although these authors did not define early and late abortions. In contrast to the negative association between metritis (MET1) and early culling reported in our study, Dohoo and Martin (1984) found that metritis diagnosed in the first three weeks post-partum was not associated with culling within 150 days. The difference might be explained by the shorter threshold dividing the two subpopulations. Furthermore, Milian-Suazo et al. (1988) reported that the time interval between diagnosis of metritis and culling was higher than 90 days for 70% of the cows involved. Thus, in agreement with our results, a positive association between metritis and late culling was found by most of the authors (Cobo-Abreu et al., 1979; Bigras-Poulin, 1985; Milian-Suazo et al., 1988; Oltenacu et al, 1990), but Dohoo and Martin (1984) reported that, after adjustment for milk production level, metritis after 20 days post-partum was protective for culling before 150 days post-partum. Contrary to some other studies (Martin et al., 1982, Bigras-Poulin, 1985; Milian-Suazo et al., 1988; Oltenacu et al., 1990), cystic ovaries were not significantly related to culling as main effects or as interaction terms. These contradictory results strongly suggest that the true effect of cystic ovaries on culling is not clear. When considering the interaction terms present in the final model for late culling, the predominance of variables related to reproductive performances (ABO1, ABO2, MET3, REPRO) was noteworthy. A possible explanation of the lower effect of REPRO and ABO1 (OR=17.4 for ABO1 and REPRO versus OR=75.8 for ABO1) was that cows aborting very early in the lactation were inseminated again and possibly were not culled. Nevertheless, most of these cows (78 %) experienced reproductive failure at 110 days post-partum (REPRO), on the basis of their interval between calving and last insemination (ICLAI). The impact of REPRO and ABO2 with regard to culling (OR=9.6 for ABO2 and REPRO versus OR=6.2 for ABO2) could be explained by the fact that cows both with days open higher than 110 days post-partum (REPRO) and aborting later in the lactation (ABO2) were considered as animals with very poor reproductive performances by the farmers and then subjects to eliminate. Likewise, the detrimental effects of calving difficulty (Oltenacu et al., 1983; Thompson et al., 1983; Erb et al., 1985) and metritis (Sandals et al., 1979; Erb et al., 1981; Oltenacu et al., 1983; Erb et al., 1985) on days open could explain the effect of ASSIST and MET3, and of MET3 and REPRO, with regard to the risk of culling. However, no tolerance with regard to reproductive performance was granted for old cows, which were at a very high risk of being culled if non pregnant at 110 days post-partum. Dohoo and Martin (1984), Erb et al. (1985), Etherington et al. (1985) found a detrimental effect of age on breeding performance after control for reproductive disorders.

Although the combination of ketosis and parity 5 only involved 24 observations (0.3 %), the very strong relative effect of this combination on early culling indicated that parity 5 potentiated the effect of ketosis or vice versa. 3 way-product terms have not been tested, but it was noteworthy that 40 % of culled cows in parity 5 with ketosis had experienced milk fever before, whereas this percentage decreased to 18 % among non culled cows in parity 5 with ketosis. A possible explanation was then that milk fever was an indirect risk factor for culling through this combination. Milk fever was indeed associated with increased odds of ketosis (Curtis et al., 1985; Bendixen, 1988; Gröhn et al., 1989).

Contrary to some other studies, digestive disorders, respiratory disorders (Dohoo and Martin, 1984) and locomotor disorders (Dohoo and Martin, 1984; Milian-Suazo et al., 1988) were not significantly related to culling in this study. The non-significance of locomotor disorders on culling might be explained in part by regular trimming and the short winter period (4 months) spent in cowsheds for the cows involved in our study.

CONCLUSION

Among nine health disorders investigated in both analyses, those influencing early and late culling differed, except one. This supports the hypothesis that culling decision-making is dependent not only on the nature of the health disorders but also on the stage of lactation of disease occurrence. Not surprisingly, periparturient events (milk fever, assisted calving) and udder disorders that might prevent milking (traumatic and non traumatic teat disorders) were risk factors for early culling. No delay could be allowed in most of these cases, since the concerned cows had possibly become non productive. Other technical (expected season of future calving) and economic (reduced receipts due to longer calving interval and lost milk production) considerations were probably taken into account in the farmers' culling decision-making process later within the lactation, since mastitis and reproductive disorders and reproductive performance were key risk factors for late culling.

These quantified parameters of prediction of longevity might provide a better understanding of farmers' culling decision process and consequently could support steps of management and culling decision-making.

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CHAPTER 3

ASSOCIATIONS BETWEEN HEALTH DISORDERS DURING TWO CONSECUTIVE LACTATIONS AND CULLING IN DAIRY COWS

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ASSOCIATIONS BETWEEN HEALTH DISORDERS DURING TWO CONSECUTIVE LACTATIONS AND CULLING IN DAIRY COWS

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ABSTRACT

Data from an observational study, carried out from 1986 to 1990, were used to quantify the effects of 15 main health disorders during two consecutive lactations on the risk of culling in the latter one. The study population consisted of 47 commercial Holstein herds from western France, comprising 4123 cows.

Logistic regression was used to assess the relationship between health disorders and culling within and after 45 days post-partum. Adjustments were made for year, month of calving, parity, breeding value for milk, best of the two first milk production records and reproductive performance. Effects of interactions were investigated. Herd effect was accounted for using random effect models.

Few diseases from the previous lactation were related to culling in the current lactation. Non-traumatic udder disorders, teat injuries, mastitis, high milk somatic cell count, abortion and metritis from the previous and current lactations were dominant with respect to culling within and after 45 days post-partum. The risk of being culled within and after 45 days post-partum increased with higher parity and lower breeding value for milk. Lower previous 305-day milk production and poor reproductive performance increased the risk of culling within and after 45 days post-partum respectively.

Key words: dairy cow, culling, disease, epidemiological risk factors

INTRODUCTION

Most studies investigating the associations between health disorders and culling are focused on the role of health disorders on culling in the same lactation (Cobo-Abreu et al., 1979; Martin et al., 1982; Dohoo and Martin, 1984; Bigras-Poulin, 1985; Erb et al., 1985; Gröhn et al., 1986; Bendixen, 1988; Bendixen and Åstrand, 1989; Milian-Suazo et al., 1989; Oltenacu et al., 1990).

Nevertheless, with regard to health management, it is reasonable to assume that the farmer's culling decision-making process is based on the entire disease history of the cow (Beaudeau et al., 1993a). Only two authors have extended the time frame of their study to more than one lactation to investigate risk factors for culling. Cobo-Abreu et al. (1979) considered all health disorders experienced in a cow's life and reported that metritis, cystic ovaries, mastitis and retained placenta were risk factors for culling. Martin et al. (1982) took into account cows with at least two consecutive lactations and found that foot problems and dystocia in the previous lactation, and metritis in the current one, were positively associated with culling, whereas ketosis in the previous one, and cystic ovaries in the current one had negative associations with culling.

The culling decision is also based on milk production. Milk production quotas in the EC have possibly led to changes in farmers' attitudes and strategies toward health management, and more specifically, toward culling decisions.

Therefore, current information concerning the short-term and the middle-term effects of health disorders on culling is essential for a more comprehensive understanding of the farmer's culling decision-making process.

The objective of this study was to investigate and to quantify the relationships between health disorders during two consecutive lactations and culling, and subsequently to assess the extent to which diseases in a lactation were predictors of culling in the following lactation.

MATERIALS AND METHODS

A prospective longitudinal survey was conducted from 1986 to 1990 in 47 commercial Holstein herds situated in western France, comprising 4123 cows. A database was designed for the storage of the information (Lescourret et al., 1993). The study population, data collection, storage and validation have been described previously (Beaudeau et al., 1993b). Data were collected in herds enrolled in a milk recording program, with cows bred by artificial insemination. Data included all lactations started between the 1 February 1986 and the 31 January 1990 and ended (by a culling or a new calving) before the 1 July 1990.

Definition of variables

The unit of observation was a pair of two consecutive lactations. Lactations ending by death were excluded from the analyses.

The population of culled cows was divided into two subpopulations, following the criteria described by Beaudeau et al. (1993b). Two dependent variables (early and late culling) were created for the investigation of risk factors for culling. The group of early cullings included: (1) cows culled within 45 days post-partum, and (2) culled cows showing only one milk record which was achieved within 30 days post-partum. The group of late cullings comprised all other culled cows. Two separate analyses were performed. In order to investigate risk factors for early culling (analysis 1), the early culled cows were compared to a group consisting of non-culled cows and late culled cows. In order to investigate risk factors for late culling (analysis 2), the late cullings were compared to a group of cows that were not culled.

The health disorders and the reproductive and milk production parameters investigated as explanatory variables are defined in Table 1. A variable dealing with milk somatic cell counts (SCC), that accounted for all milk cell counts available throughout lactation, was defined according to Serieys (1985). Three status modalities were determined for the variable SCC. The status SCCA was assigned to the cows with all milk somatic cell count records below 300 000 cells/ml throughout lactation. The status SCCB was assigned to the cows with (1) at least one record between 300 000 and 800 000 cells/ml and no record higher than 800 000 cells/ml or (2) only one record higher than 800 000 cells/ml and the others below 300 000 cells/ml. The status SCCC was assigned to cows characterized by other cases with regard to somatic cell count values.

Infertility was measured using an indicator (REPRO) based on the status of the cow: with or without reproductive failure at 110 days post-partum. For cows culled before 110 days post-partum, the reproductive status was defined at culling and assigned to the variable REPRO. First, REPRO was based on the interval between calving and the last registered artificial insemination (ICLAI), for each lactation of cows served by artificial insemination. If ICLAI was larger than 110 days, the cow was assigned as having reproductive failure at 110 days post-partum. Second, reproductive failure was defined to be present in cows that were not inseminated and culled after 110 days post-partum, or in cows that were not inseminated and culled for a reason related to reproductive ability. In all other cases, the cow was assumed to be free of reproductive failure at 110 days post-partum. 305-day milk production (305MP) and best of the two first milk production records (START) were included in the analyses, to assess the impact of milk production on culling. For each observation, year of calving, month of calving, parity of the current lactation, and breeding value for milk were also accounted for. The breeding value for milk of each cow (BVM) was evaluated according to Bonaiti et al. (1990), and corresponded to its estimation on February 1992. Because of the low number of early cullings, cows with missing breeding value for milk were excluded from analysis 1.

Records of cows for which at least two subsequent lactations were available were used for the analyses. The former lactation of the pair was named "previous" and the latter one "current". A prefix "P" was attached to variables applying to the previous lactation. Table 1 gives the variables included as possible risk factors for culling in analyses 1 and 2.

Statistics

The model-building process used for both analyses involved four stages. The first three stages were carried out using the LOGISTIC procedure of SAS (SAS Institute Inc., 1989), according to the method described by Hosmer and Lemeshow (1989).

In the first stage, an univariate logistic regression analysis was done to relate culling to each possible health disorder of both previous and current lactations. Only factors associated to culling ($P < 0.25$ - likelihood ratio chi-square test) were offered to multivariate models.

Table 1. Description of disease, reproductive and milk production variables from the previous and current lactations taken into account in the analysis 1 (early culling) and in the analysis 2 (late culling)

Abbreviation		Definition
Current lactation	*Previous* lactation	
Reproductive performance and milk production variables		
REPRO[1]	P-REPRO	reproductive indicator at 110 days post-partum
START[1]	P-START[2]	best of the two first milk records (kg)
305MP[2]	P-305MP	305-day milk production (kg)
BVM	-	breeding value for milk (kg)
Disease variables[3]		
ABO1[1]	P-ABO1	abortion from 100 to 180 days of gestation
ABO2[1]	P-ABO2	abortion at more than 180 days of gestation
ACC	P-ACC	accident, trauma, haemorrhage of genital tractus, embryotomy, caesarean section, leg paralysis diagnosed at 10 days or less post-partum
ASSIST	P-ASSIST	calving provided with assistance
DIG[1]	P-DIG	miscelleanous digestive disorders
KETO	P-KETO	ketosis or loss of appetite without any concurrent health disorders within a [-3,+3] days interval, diagnosed at 45 days or less post-partum
LOC[1]	P-LOC	foot and leg disorders
MAS1	P-MAS1	mastitis diagnosed at 45 days or less post-partum
MAS2[1]	P-MAS2	mastitis diagnosed from 46 to 90 days post-partum
MAS3[1]	P-MAS3	mastitis diagnosed from 91 to 180 days post-partum
MAS4[1]	P-MAS4	mastitis diagnosed from 181 to 270 days post-partum
MAS5[1]	P-MAS5	mastitis diagnosed at 271 days or more post-partum
MASD[2]	P-MASD	mastitis diagnosed within the dry period
MET1	P-MET1	vaginitis, vulvitis, vulvo-vaginitis, endometritis, vaginal discharge, metritis, pyometritis diagnosed at 21 days or less post-partum
MET2[1]	P-MET2	vaginitis, vulvitis, vulvo-vaginitis, endometritis, vaginal discharge, metritis, pyometritis diagnosed from 22 to 49 days post-partum
MET3[1]	P-MET3	vaginitis, vulvitis, vulvo-vaginitis, endometritis, vaginal discharge, metritis, pyometritis diagnosed at 50 days or more post-partum
MF	P-MF	milk fever
OVA1[1]	P-OVA1	cystic ovaries diagnosed from 46 to 90 days post-partum
OVA2[1]	P-OVA2	cystic ovaries diagnosed from 91 to 150 days post-partum
OVA3[1]	P-OVA3	cystic ovaries diagnosed at 151 days or more post-partum
RES1[1]	P-RES1	respiratory disorders diagnosed at 150 days or less post-partum
RES2[1]	P-RES2	respiratory disorders diagnosed at 151 days or more post-partum
RP	P-RP	retained placenta (>12 hours)
SCC[1]	P-SCC	milk somatic cell count
TEA1	P-TEA1	teat injuries diagnosed at 45 days or less post-partum
TEA2[1]	P-TEA2	teat injuries diagnosed at 46 days or more post-partum
UDD1	P-UDD1	non traumatic udder disorders diagnosed at 45 days or less post-partum

[1] not used in analysis 1;
[2] not used in both analyses 1 and 2
[3] for each variable, the cow was positive when the event occurred at least once.

The second stage included all the diseases that passed the first stage, plus REPRO for analysis 2. Dummy variables for year of calving, month of calving, parity, BVM, P-MP305 and P-REPRO were in all models, irrespective of their level of significance. START was in all models for analysis 2. Wald's test was used to assess the significance of each term in the model (Wald, 1943). The variable with the highest P was removed and the logistic regression was rerun. The process was continued until a model was obtained with all diseases significant at $P < 0.10$ (model A).

In the third stage, two-way interaction terms among the variables were considered. All diseases were hypothesized to interact with each other and with reproductive status, parity, and milk production parameters. Each interaction was tested by its addition alone to model A, and only interaction terms significantly related to culling ($P < 0.25$) were kept. All the retained interaction terms were then added simultaneously to model A to obtain model B. A backward procedure based on the likelihood ratio chi-square statistic was performed until a final model was obtained with significant ($P < 0.10$) interactions (model C).

In the fourth stage, a random-effect logistic model with herd as main plot was used to account for the fact that cows within herds might not be independent (Curtis et al., 1993). The logistic binomial regression model, which assumes that the random perturbation in the binomial proportion follows a standardized binomial distribution, was run as a special case of Jansen's method for ordinal data (Jansen, 1990). The number of quadrature nodes was set to 5. Computations were carried out using a FORTRAN program developed by Jansen. Interaction terms that became non-significant were removed, and the model was re-fit with the remaining variables until a final model was obtained with significant interactions ($P < 0.10$). The deviance difference is a likelihood ratio statistic and was used to assess the goodness-of-fit for each model (McCullagh and Nelder, 1989).

The regression coefficients from logistic binomial regression were exponentiated to obtain the odds ratio (OR) and its 90 % confidence interval (CI) associated to each covariate. An odds ratio greater than unity implies an increased risk of culling. In this case, the relationship between the covariate and culling is positive. An odds ratio lower than unity implies that there is a decreased risk of culling following the concerned disease. In this case, the relationship is negative.

RESULTS

The final logistic regression models corresponding to analysis 1 and analysis 2 are summarized in Tables 2 and 3.

Health disorders as risk factors for early culling (analysis 1)

3223 pairs of two consecutive lactations were considered in this analysis. 151 pairs of lactations ended by an early culling and 3072 pairs of lactations showed no early culling. 168 observations had been deleted because of missing P-305MP and/or BVM.

Table 2. Variables and variable categories in the final logistic regression model for risk factors for early culling (3223 pairs of two consecutive lactations) and their relation to culling. Only variables or combinations of variables significantly related to culling (*P* < 0.10) are reported.

Variable[1]	Percentage of pairs of lactations (%)	Odds ratio	90% CI
Current lactation			
Parity			
parity 2	29.0	1.0	-
parity 3 and 4	41.4	2.2	1.3 - 3.6
parity 5 and more	29.6	4.6	2.7 - 7.7
Breeding value for milk (BVM) (kg)			
<400	32.8	1.8	1.2 - 2.6
400 - 800	34.1	1.0	-
Ketosis (KETO)	3.6	5.0[2]	2.3 -10.9
Teat injuries (TEA1)	1.0	4.6	2.0 -10.4
Non traumatic udder disorders (UDD1)	1.9	3.3	1.6 - 6.8
Previous lactation			
305-day milk production (P-305MP) (kg)	-	0.8[3]	0.7 - 0.9
Teat injuries (P-TEA2)	1.0	3.6	1.4 - 9.0
Non traumatic udder disorders (P-UDD2)	1.2	3.2	1.3 - 8.3
Milk somatic cell count (P-SCC)			
status P-SCCA	53.2	1.0	-
status P-SCCC	17.2	2.0[2]	1.3 - 3.0
Interactions			
status P-SCCC and KETO	0.6	4.4[4]	1.3 -14.5

Deviance difference of model=167.2 with 19 d.f. (*P* < 0.001); random-effect coefficient: s=0.72; SE(s)=0.12.

[1] In addition, year of calving (reference=1988), season of calving (reference=August to November) were included in the model.

[2] given that the value of the other variables involved in interaction terms was equal to 0.

[3] unit: 1 000 kilograms increase of P-305MP (range: 4385 - 12471).

[4] Reference for combinations of health disorders was absence of any health disorder.

Higher parities (3 and more) were at increased risk of being culled, in comparison to parity 2. A lower breeding value for milk was positively associated with the risk of culling. Each increase of 1000 kilograms in the value of P-MP305 increased the risk of being culled 0.8-fold. Ketosis (KETO), teat injuries (TEA1) and non-traumatic udder disorders (UDD1) were positively related to culling as direct effects. Only 3 disease conditions from the previous lactation - teat injuries and non-traumatic udder disorders occurring after day 45 (P-TEA2, P-UDD2), high milk somatic cell count (P-SCCC) - were positively associated with culling (OR=3.6, 3.2, 2.0 respectively).

Furthermore, a cow having experienced both the status P-SCCC and KETO had a 4.4 times higher risk of being culled than a cow without these two diseases.

Health disorders as risk factors for late culling (analysis 2)

3058 pairs of two consecutive lactations, including 982 late cullings and 2076 observations ending by a new calving, were considered in this analysis. 278 observations were deleted because of missing P-305MP and/or START. Pairs of lactations from the group of early cullings were not taken into account.

A cow in parity 5 or more had a higher risk of being culled than a cow in parity 2. An increased breeding value for milk was negatively associated to culling, following an apparent progressive trend. P-305MP was not significantly related to culling, but for an increase of 5 kilograms in the value of START, the risk of culling increased 0.7-fold.

5 disease conditions occurring in the current lactation (ABO1, ABO2, ASSIST, MAS2, MET1) were positively associated with culling as direct effects. However, a cow characterized by the status SCCB or SCCC had a 0.7 time higher risk of being culled than a cow with the status SCCA. Cows experiencing P-ABO1, the status P-SCCB or P-SCCC had a higher risk of being culled after 45 days post-partum than cows without these events (OR=6.2, 1.4, 2.0 respectively).

Mastitis occurring within 45 days post-partum (MAS1) or between 90 and 180 days post-partum (MAS3) was not significantly related to culling as direct effects, but a cow with both MAS1 and the status SCCB or MAS3 and the status SCCC was at increased risk of being culled compared to cows free of these health disorders (OR=1.8 and OR=2.2 respectively). A cow with MAS2 and P-REPRO or REPRO had a higher risk of being culled than a cow with MAS2 only. P-ACC (periparturient accident in the previous lactation) potentiated the effect of MAS1 or vice versa (OR=19.4), although these health disorders were non-significant as main effects.

Table 3. Variables and variable categories in the final logistic regression model for risk factors for late culling (3058 pairs of two consecutive lactations) and their relation to culling. Only variables and combinations of variables significantly related to culling (P < 0.10) are reported.

Variable[1]	Percentage of pairs of lactations (%)	Odds ratio	90% CI
Current lactation			
Parity			
parity 2	29.8	1.0	-
parity 5	12.1	1.7	1.2 - 2.2
parity 6	8.5	2.9	2.0 - 4.1
parity 7 and more	8.0	2.2	1.6 - 3.2
Breeding value for milk (BVM) (kg)			
missing	0.9	3.4	1.4 - 7.8
<0	7.8	1.4	1.1 - 2.0
0 - 400	23.7	1.5	1.2 - 1.9
400 - 800	34.2	1.0	-
800 - 1200	23.3	0.7	0.6 - 0.9
>1200	10.2	0.5	0.4 - 0.7
Best of the two first milk records (START) (kg)	-	0.7[2]	0.6 - 0.8
Abortion (ABO1)	0.7	3.3	1.4 - 8.0
Abortion (ABO2)	1.1	3.2	1.7 - 6.1
Calving provided with assistance (ASSIST)	5.9	1.5	1.1 - 2.1
Mastitis (MAS2)	6.4	2.1[3]	1.4 - 3.2
Metritis (MET1)	6.9	1.7	1.3 - 2.3
Milk somatic cell count (SCC)			
status SCCA	47.0	1.0	-
status SCCB	30.6	0.7[3]	0.6 - 0.8
status SCCC	22.4	0.7[3]	0.5 - 0.9
REPRO	41.8	6.2[3]	5.3 - 7.4
Previous lactation			
Abortion (P-ABO1)	0.4	6.2	1.8 -21.2
Cystic ovaries (P-OVA3)	0.5	0.2	0.1 - 0.8
Milk somatic cell count (P-SCC)			
status P-SCC	53.5	1.0	-
status P-SCCB	29.7	1.4[3]	1.2 - 1.7
status P-SCCC	16.7	2.0[3]	1.5 - 2.5
P-REPRO	28.2	0.7[3]	0.6 - 0.8
Interactions			
Accident (P-ACC) and Mastitis (MAS1)	0.2	19.4[4]	2.6 -142
Mastitis (MAS1) and status SCCB	3.8	1.8[4]	1.2 - 2.7
Mastitis (MAS2) and P-REPRO	2.0	2.9[4]	1.6 - 5.2
Mastitis (MAS2) and REPRO	2.8	5.4[4]	3.4 - 8.5
Mastitis (MAS3) and status SCCC	4.5	2.2[4]	1.3 - 3.8

Deviance difference of model=794.2 with 51 d.f. (P < 0.001); random-effect coefficient: s=0.42; SE(s)=0.09.

[1] In addition, year of calving (reference=1988), month of calving (reference=October) were included in the model.

[2] unit: 5 kilograms increase of START (range: 14.5 - 55.1).

[3] given that the value of the other variables involved in interaction terms was equal to 0.

[4] Reference for combinations of health disorders was absence of any health disorder.

Additional historical risk of culling

When taking the risk of culling due to the occurrence of diseases in the current lactation as the reference, the additional (multiplicative) risk of culling due to the occurrence of health disorders in the previous lactation showed large variations. When not involved in interaction terms with events from the current lactation, the events from the previous lactation had an additional effect on culling, equal to their corresponding odds ratio. For instance, the additional risk on early culling due to the occurrence of P-UDD2 was 3.2, irrespective of the nature of the health disorder occurring in the current lactation (see Table 2). Likewise, the additional risk on late culling due to P-ABO1 was 6.2 (see Table 3). In most cases, this odds ratio exceeded unity and, consequently, the risk of being culled was increased by the occurrence of health disorders in the previous lactation. However, when dealing with recurrence of events in two consecutive lactations, opposite effects were noted. Cows with P-REPRO and REPRO had a significantly lower risk of being culled than cows with REPRO only (OR=4.3 vs OR=6.2). The additional effect of the status P-SCCB or P-SCCC on culling for a cow characterized by the status SCCB or SCCC was positive.

Opposite effects on culling, due to the occurrence of events from the previous lactations could also be noticed, especially because of interactions between diseases from the previous and the current lactations (Table 4).

Table 4. Additional risk of early and late culling in the current lactation due to the occurrence of events from the previous lactation involved in interaction terms with events from the current lactation in the final model.

Additional effect tested[1]	Additional risk[2] (Odds ratio)	90% CI
Risk of early culling		
case 1 - (status P-SCC3 and KETO) vs KETO	0.9	0.2 - 3.6[NS]
Risk of late culling		
case 2 - (P-ACC and MAS1) vs MAS1	21.9	3.0 -157
case 3 - (P-REPRO and MAS1) vs MAS1	1.3	0.8 - 2.1[NS]
case 4 - (P-REPRO and MAS2) vs MAS2	1.4	0.8 - 2.5[NS]
case 5 - (status P-SCCB and MAS3) vs MAS3	1.2	0.6 - 2.2[NS]
case 6 - (status P-SCCC and MAS3) vs MAS3	0.7	0.3 - 1.4[NS]

[NS]Non significant ($P = 0.10$).

[1]for definition, see Table 1.

[2]The reference was the presence of a disease in the current lactation. This additional risk was multiplicative of the reference risk due to the occurrence of the event from the current lactation only.

DISCUSSION

The dataset included 1061, 891 and 183 cows which respectively experienced two, three and four complete lactations recorded in this study. Therefore, in the two latter cases, more than one pair of consecutive lactations per cow were available. Taking into account all the pairs of consecutive lactations of a cow could have induced bias because of lack of independency between observations. However, performing a random effect model with cow as main plot implied huge computing time and was not deemed feasible. Finally, this method allowed to account the fact that more than 50 % of the cows had experienced more than two lactations during the study period and then to retain as much information as possible.

The division of culled cows into two populations was intended to assess the hypothesis that the farmers' culling decision-making process was probably not the same for cows culled early in lactation as for cows culled later. However, considering the relatively low number of early cullings, a generalization of corresponding results must be done with caution. Additionally, some interaction terms in the two final models involved a low percentage of observations each (less than 1%). Therefore, the interpretation of these interaction terms must be cautious.

Best of the two first milk production records (START) was assumed to reflect the actual individual milk production potential. Wilmink (1987) reported that the last known test-day yield at 50 days post-partum could be relevantly used to predict 305-day milk yield. Controlling for START made it possible to assess the full impact of diseases on culling. If the adjustment for milk production in analysis 2 had concerned 305-day milk production in the current lactation (305MP) instead of START, the odds ratio attached to 305MP would have included a part of the impact of some diseases on culling, because of the effect of these diseases on cumulative milk production.

The identification of variables from both the previous and the current lactation that affected culling confirmed the hypothesis that culling decision depended not only on diseases occurring in the lactation of culling, but also on the whole disease history of the cow.

The effect of the occurrence of health disorders in one lactation on the risk of culling in the following one appeared to be low, in terms of number of diseases significantly related to culling in the final models. Of the 28 health disorders from the previous lactation tested in the unconditional screening (Table 1), only 3 and 4 disease conditions finally remained significant after adjustment for other individual characteristics and health disorders occurring in the current lactation (Tables 2 and 3, respectively). This suggests that short-term effects investigated here are dominant in the culling decision making. Furthermore, variations in the additional risk of culling due to the occurrence of health disorders in the previous lactation stress the fact that culling decision is a complex process.

The health disorders occurring in the previous lactation, and found as risk factors for culling decisions within or after 45 days post-partum in the current lactation were related to udder health (P-TEA2, P-UDD2, status P-SCCB, status P-SCCC), to reproductive disorders (P-ABO1, P-OVA3) and to reproductive performance (P-REPRO). Thus, reproductive performances and udder health appeared to be criteria for middle-term culling decisions. However, the events occurring in the previous lactation did not result, per se, in a culling in the same lactation. Consequently, one could suggest that these health disorders were not considered by the farmers to be severe enough to have a short-term impact on culling, and/or that the culling decision was rather based on priority-criteria not related to health.

The lower risk of being culled for cows with recurrence of poor reproductive performance in two consecutive lactations (P-REPRO and REPRO) in comparison to cows with REPRO only, could be due to a selection bias. By definition, the individuals taken into account in this study were not culled at the end of the previous lactation, despite poor reproductive performances. An explanation could be that these cows were kept because of their high potential and actual level of milk production. The cows with P-REPRO showed significantly higher P-305MP and BVM than the cows without any reproductive failure at 110 days post-partum ($P < 0.05$). However, cows with poor breeding performance in two consecutive lactations had a 4.3 higher risk of being culled than cows without any reproductive problems.

Although the status P-SCCB or P-SCCC had a significant additional effect on culling in the subsequent lactation, the occurrence of both the status P-SCCB or P-SCCC and SCCB or SCCC did not increase the risk of late culling, compared to a healthy status (SCCA). Such results could suggest that culling decisions would be postponed with the occurrence of high milk somatic cell counts, possibly because of the simultaneous occurrence of other clinical diseases deemed more important by the farmers. It is reasonable to think that the ranking of health disorders as priority-risk factors for culling may strongly vary from one farmer to another. Additionally, the culling decision is also based on economic considerations (e.g. reduced milk receipts due to lower milk quality).

The negative association between P-305MP and culling within 45 days post-partum could be interpreted as an additional risk for culling decisions: no opportunity to recover was offered to these cows, given their low level of milk production. The non-significant association between P-305MP and culling decisions after 45 days post-partum may be explained by the fact that culling was considered, in the present study, as a simple event irrespective of the culling reasons. Milian-Suazo et al. (1989) reported that the previous average milk production per day was negatively associated with certain reasons for culling, e.g. low milk production. However, our results are supported by Martin et al. (1982) and Erb et al. (1985), who found no significant relationship between previous milk yield and culling. A lower breeding value for milk was associated with a higher risk of being culled in the present study. It was noted that the individual breeding values for milk taken into account in the present study were estimated in February 1992. These values were therefore more precise and consequently different from the individual breeding values for milk which were available to the farmers during the study period.

Dealing with the relationship between health disorders occurring in the current lactation and culling within and after 45 days post-partum (both in the same lactation), the relevancy of direct comparisons with other studies performed at the lactational level might be limited. First, the present study only involved multiparous cows, showing at least two lactations, and hence representing a particular population. Second, the effects of the health disorders from the current lactation were adjusted for the events occurring in the previous lactation. Finally, the strategy of analysis used in the present study implied two separate analyses whether the cows were culled within or after 45 days post-partum. However, in agreement with analyses performed at the lactational level (Beaudeau et al., 1993b), ketosis, traumatic and non-traumatic udder disorders were positively related to culling within 45 days post-partum, whereas mastitis, reproductive disorders (abortion, metritis) and reproductive performance appeared to be key risk factors for culling after 45 days post-partum.

CONCLUSION

The investigation into the relationships between health disorders from two consecutive lactations and culling confirms that udder health and reproductive disorders from both previous and current lactations were the main health related criteria involved in the culling decisions, irrespective of whether the cows were culled before or after 45 days post-partum.

As a general rule, culling appeared to be firstly related to short-term effects, rather than to the consideration of the whole disease history of the cow. The additional effects on risk of culling due to the occurrence of health disorders in the previous lactation were dependent upon the nature of the diseases the cow experienced in both previous and current lactations. The results suggest that farmers mainly take into account events of the current lactation in their decision-making process about culling. Further research is needed to investigate the interest of accounting for the entire disease history of the cow to make culling decisions.

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RESUME

Associations entre troubles de santé survenant dans deux lactations consécutives et réforme chez la vache laitière.

Des données issues d'une enquête longitudinale prospective conduite dans 47 troupeaux bovins laitiers Holstein de l'ouest de la France de 1986 à 1990 ont été utilisées pour quantifier l'impact de 15 troubles de santé survenant dans deux lactations consécutives sur le risque de réforme.

Deux analyses par régression logistique ont été réalisées pour établir les relations entre ces troubles de santé et les décisions de réforme précoce (jusqu'à 45 jours après vêlage) ou tardive (plus de 45 jours après vêlage). Chaque analyse a été ajustée sur l'année et le mois de vêlage, la parité, l'index lait, la production laitière au meilleur des deux premiers contrôles laitiers et la performance de reproduction. Les interactions ont été étudiées. Des modèles à effet aléatoire ont été utilisés pour prendre en compte l'effet troupeau.

Peu de troubles de santé survenant dans une lactation sont liés à la réforme dans la lactation suivante. Les troubles de santé liés à la mamelle (affection non traumatique de la mamelle, blessure du trayon, mammite, taux cellulaire élevé du lait) et certains troubles de reproduction (avortement, métrite) sont les facteurs de risque majeurs de la réforme précoce et de la réforme tardive. Une vache avec un numéro de lactation élevé et/ou avec un index lait faible a un risque de réforme précoce ou tardive accru. Une production laitière en 305 jours faible dans une lactation accroît le risque de réforme précoce dans la lactation suivante. De faibles performances de reproduction augmentent le risque de réforme tardive dans la même lactation.

ZUSAMMENFASSUNG

Zusammenhang zwischen Gesundheitsstörungen in zwei aufeinander folgenden Laktationen und Ausfall bei Milchvieh

Daten, die in einer Longitudinalstudie während viereinhalb Jahren (vom 1986 bis 1990) zusammengetragen wurden, wurden verwendet um den Einfluß von 15 häufig auftretende

Gesundheitsstörungen in zwei aufeinander folgenden Laktationen auf das Risiko von Verlusten in der darauffolgenden Laktation zu kwantifizieren. Die Studienpopulation bestand aus 4123 Milchkühen von 47 Herden (Hollstein Frisian) im Westen Frankreichs.

Der Zusammenhang zwischen diesen Gesundheitsstörungen, die während zwei aufeinander folgenden Laktationen auftraten und dem Ausfall innerhalb von 45 Tagen und nach 45 Tagen post partum in der darauffolgenden Laktation (normale Todesfälle nicht mitgerechnet) wurden mit Hilfe der Logistischen Regression berechnet. Korrekturen wurden für Jahr, Abkalbmonat, Zuchtwert für Milchleistung, Parität und Fortpflanzungseigenschaften ausgeführt. Von den ersten zwei notierten Milchleistungen wurde die beste gewählt. Mögliche gegenseitige Wechselwirkungen von Variabelen wurden ebenso untersucht. Der Herdeneinfluß wurde im analytischen Modell als Zufallseffect aufgenommen.

Euter-Gesundheitsstörungen (a-traumatische Euterverletzungen, Zitztenverletzungen, Mastitis und erhöhter Milchzellgehalt) und einige Fortpflanzungsstörungen (Abortus und Gebärmutterentzündungen) der vorhergehenden und laufenden Laktation waren dominant in Bezug auf den Ausfall innerhalb und nach 45 Tagen post partum. Einige wenige Erkrankungen der vorhergehenden Laktation hatten einen signifikanten Einfluß auf den Ausfall in der laufenden Laktation. Das Risiko auf Ausfall wurde geringer bei vortlaufender Parität und niedrigen Zuchtwerten für Milchleistung. Eine niedrige 305-Tage Milchproduktion und schlechte Fortpflanzungseigenschaften waren positiv korreliert mit dem Ausfall sowohl während als auch nach 45 Tagen post partum.

CHAPTER 4

ACCOUNTING FOR TWO LEVELS OF NESTED EFFECTS IN MULTIPLE LOGISTIC REGRESSION ANALYSIS: APPLICATION TO THE ASSESSMENT OF COW-LEVEL RISK FACTORS FOR CULLING IN DAIRY HERDS

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ACCOUNTING FOR TWO LEVELS OF NESTED EFFECTS IN MULTIPLE LOGISTIC REGRESSION ANALYSIS: APPLICATION TO THE ASSESSMENT OF COW-LEVEL RISK FACTORS FOR CULLING IN DAIRY HERDS

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ABSTRACT

Data from an observational study were used to assess the relationships between health disorders and culling at the 'random one pair of lactations' (ROP) level (accounting for two levels of nested effects, i.e. herd and cow) and at the 'all pairs of lactations' (AP) level (ignoring the dependency between lactations, i.e. violating the assumption of independency between observations), by means of logistic regression analysis.

At the ROP level, 10 random selections of one pair of lactations per cow were done. From the 10 random samples, a disease was considered as significantly associated to culling, if present in at least 4 final models. At the AP level, all the available pairs of lactations were included in analyses.

The ROP level analyses showed qualitative and quantitative variations between the 10 final models. Using a single random sample might give incomplete information.

There was an overall agreement in results when accounting or not for dependency of observations. All diseases significantly related at the AP level, except two, were considered as significantly associated to culling at the ROP level. However, quantitative variations in the regression coefficients between models performed at the ROP level and the AP level put forward the importance of dispersion parameters.

Key words: culling, disease, cluster effect, logistic regression

INTRODUCTION

Multiple logistic regression has been described as a relevant method to investigate risk factors associated to dichotomous outcomes (Breslow and Day, 1980). The use of ordinary logistic regression requires the assumptions that the individuals are independent. However, in most field surveys, the unit of sampling is a group of animals (herd, litter), and ordinary logistic regression is often not appropriate, because animals are not identically distributed (Curtis et al., 1993a).

Several methods are available to account for the group effects. A first way is to model them as fixed effects. Mauritsen (1984), cited by Curtis et al. (1993a), has put forward the disadvantages of this method. Other models can also be used: conditional logistic regression, random-effects logistic regression (beta-binomial, logistic-normal and logistic-binomial regression). Random-effect logistic-binomial regression was deemed the most appropriate method to model dichotomous outcomes when analysis was done at the individual level, but animals are grouped (Curtis et al., 1993a).

The inclusion of a random-effect term in the logistic regression models is now widely used in epidemiological studies (Wittum et al., 1990; Goelema et al., 1991; Frankena et al., 1992; Curtis et al., 1993b; Frankena et al., 1993; Beaudeau et al., 1994a, 1994b). In these studies, the random effect term accounts for the heterogeneity between herds with respect to the probability of the outcome; the herd was then the main plot.

The productive life of most large animals is rythmed by biological cycles, especially lactations in cattle. Thus, in most epidemiological surveys involving cows, data (demographic data, diseases, reproductive performances) are recorded on a lactational basis and the unit of observation considered in analyses is often the lactation, sometimes as an approximation of the cow. Then, a new problem can arise because lactations within cow are not independent. When analysing data at the lactational level, control for both cow and herd effects theoretically is needed.

In studies investigating health disorders as risk factors for culling, all authors focused on the role of health disorders on culling in the same lactation. Strictly speaking, the analyses were performed at the lactational level. Herd effect was accounted for by Martin et al. (1982), Dohoo and Martin (1984) and Erb et al. (1985). In some studies, only one lactation per cow was available considering the duration of the study period (Martin et al., 1982; Oltenacu et al., 1984; Gröhn et al.,1986). In such cases, the lactational level was in fact the cow level. In other studies, all the available lactations were considered (Dohoo and Martin, 1984; Erb et al., 1985; Bendixen, 1988; Bendixen and Åstrand, 1989), but the cow effect was not accounted for. An explanation can be that modelling herd and cow effects as fixed effects was not considered feasible (because of huge time computing), or that no software was available to researchers to account for random effects at two levels (herd and cow). The same limits were observed when considering disease history of cows on two consecutive lactations for determining pairs of lactations to be included in analyses. Possible bias, induced by non-independency of observations, in computed solutions were not evaluated.

The objectives of the present study were (1) to propose a method accounting for two levels of nested effects in multiple logistic regression analysis to investigate health disorders as risk factors for culling in dairy herds, (2) to assess differences in computed solutions to those resulting from ignoring the assumption of independency between observations.

MATERIALS AND METHODS

Data

The study population, data collection, storage and validation have been described previously (Beaudeau et al., 1994a). Data were recorded in 47 commercial Holstein herds, situated in Western France, enrolled in a milk recording program, with cows served by artificial insemination. Data included all lactations started between 1 February 1986 and 31 January 1990 and ended (by a culling or a new calving) before 1 July 1990.

A total of 16 disease conditions, reproductive performance and milk production parameters were investigated as possible risk factors for early and late culling. Definitions of these variables are shown in appendix. Two dependent variables (early and late culling) were created for the investigation of risk factors. The group of early cullings included (1) the cows culled within 45 days post-partum, and (2) the culled cows showing only one milk record which was achieved within 30 days post-partum. All other cullings were considered as late cullings (Beaudeau et al., 1994a).

Modelling

Whatever the level of analysis considered, two separate analyses were performed. In order to investigate diseases as risk factors for early culling, the early-cullings group was compared to a group consisting of not-culled cows and cows in the late-culling group. In order to investigate diseases as risk factors for late culling, the late culling group was compared to a group including cows which were not culled.

The model-building process used for both analyses has been described previously (Beaudeau et al., 1994b). It involved three stages. The two first were carried out using the LOGISTIC procedure of SAS (SAS Institute Inc., 1989), according to the method described by Hosmer and Lemeshow (1989). A univariate analysis was performed to relate culling to each possible health disorder occurring in both previous and current lactations. Only factors associated to culling ($P < 0.25$ - likelihood ratio chi-square test) were offered to multivariate models. Multivariate models were used performing a backward procedure based on the likelihood ratio chi-square statistic, until a final model was obtained with all diseases significant at $P < 0.10$. In the third stage, a random-effect logistic model with herd as main plot was used to account for the fact that cows within herds might not be independent. The logistic-binomial regression model, which assumes that the random perturbation in the binomial proportion follows a standardized binomial distribution, was run as a special case of Jansen's method for ordinal data (Jansen, 1990). The number of quadrature nodes was set to 5. Computations were carried out using a FORTRAN program. Disease conditions which became non significant were removed using a backward procedure until a final model was obtained with only significant diseases ($P < 0.10$).

Analyses

The original dataset included 1016, 934, 113 cows which experienced two, three and four complete lactations respectively during the study period. The unit of analysis was the pair of two consecutive lactations. In total, 3223 pairs of lactations were available. The former lactation of the pair was named "previous" and the latter one "current". Thus, a prefix "P" was attached to variables applying to the previous lactation in all models.

All pairs of consecutive lactations were used, in analyses AP1 and AP2 (All Pairs, early and late culling respectively), ignoring the fact that these pairs were not independent within cows.

To account for non-independency of lactations within cows, one pair of two consecutive lactations per cow was randomly selected using the PLAN procedure of SAS (SAS Institute, 1989) in analyses ROP1 and ROP2 (Random One Pair, early and late culling respectively). In order to account for the variability in effects due to the random selection, analyses ROP1 and ROP2 were performed 10 times.

Considering α set for keeping variables in each model, a disease not associated to culling would be retained in up to 10% of all possible models provided by random selection. Then, a disease can be considered as significantly associated to culling if the proportion π of models including it is over 0.10 in the population of all models. The 10 final models were viewed as a sample of all possible models. In this sample, the proportion (PP) of models in which the concerned disease was significantly ($P < 0.10$) related to culling, was calculated. PP for a given disease follows a binomial distribution (Snedecor and Cochran, 1980). Given N equal to 10, PP had to be at least equal to 0.4 to conclude, at a 10% risk level, that π was over 0.10. Therefore, a disease had to be at least present in 4 models to be considered as significantly associated with culling.

Within analyses ROP1 and ROP2, qualitative 2 by 2 between-final models comparisons were performed by calculating the number and percentages of mismatches between two given models, defined as the number of diseases retained in one final model and not in the other one, divided by the total number of diseases retained in all models.

For all diseases significantly associated to culling based on PP, means of their n associated regression coefficients (β) and standard errors of the mean of β from logistic binomial regression were calculated. These parameters were compared to corresponding regression coefficients and standard errors resulting from analyses AP1 and AP2.

RESULTS

The incidence of the health disorders taken into account in the analyses is displayed in Table 1.

Table 1. Incidence of the health disorders (2063 Holstein cows in western France)

Health disorder	Incidence per lactation (%)
Abortion from 100 to 180 days of gestation	0.9
Abortion at more than 180 days of gestation	1.1
Accident, trauma, embryotomy, caeserean section, leg paralysis diagnosed at 10 days or less post-partum	1.6
Calving provided with assistance	8.2
Miscelleanous digestive disorders	4.5
Ketosis or loss of appetite diagnosed at 45 days or less postpartum	2.9
Foot and leg disorders	14.2
Milk fever	7.7
Mastitis diagnosed at 45 days or less postpartum	11.3
Mastitis diagnosed from 46 to 90 days postpartum	5.2
Mastitis diagnosed from 91 to 180 days postpartum	6.5
Mastitis diagnosed from 181 to 270 days postpartum	4.1
Mastitis diagnosed at 271 days or more postpartm	1.7
Mastitis diagnosed during the dry period	2.0
Milk somatic cell count status	
- healthy	51.1
- doubtful	29.5
- infected	19.4
Teat injuries and trauma diagnosed at 45 days or less postpartum	0.5
Teat injuries and trauma diagnosed at 46 days or more postpartum	1.0
Non traumatic udder disorders diagnosed at 45 days or less postpartum	2.1
Non traumatic udder disorders diagnosed at 46 days or more postpartum	1.2
Metritis diagnosed at 21 days or less postpartum	8.0
Metritis diagnosed from 22 to 49 days postpartum	6.8
Metritis diagnosed at 50 days or more postpartum	6.5
Retained placenta	10.8
Cystic ovaries diagnosed from 46 to 90 days postpartum	2.5
Cystic ovaries diagnosed from 91 to 150 days postpartum	1.4
Cystic ovaries diagnosed at 151 days or more postpartum	0.6
Respiratory disorders at 150 days or less postpartum	3.0
Respiratory disorders at 151 days or more postpartum	1.9

Between-final models comparison

Tables 2 and 3 give between-final-models comparisons for disease conditions. 13 and 21 disease conditions were related at least once to early and late culling respectively. The number of significant parameters varied from 3 to 8 and from 8 to 14 per model depending of the sample. After estimation of their corresponding PP, 6 and 11 disease conditions could be considered as significantly associated to early and late culling respectively.

Table 2. Diseases significantly related (P < 0.10) to early culling in each final model and proportion of models in which the corresponding disease was a risk factor.

Disease[1]	Sample										Proportion
	1	2	3	4	5	6	7	8	9	10	PP[2]
P-MAS2	N[a]	N	N	N	N	N	N	N	Y[b]	N	0.1
P-MAS5	N	Y	N	N	N	N	N	N	N	N	0.1
P-MASD	Y	Y	N	N	N	N	N	N	N	Y	0.3
P-MET3	Y	N	N	N	N	N	N	N	N	N	0.1
P-OVA1	N	N	N	N	N	Y	N	N	N	N	0.1
P-RES1	N	Y	N	N	N	N	N	N	N	N	0.1
P-TEA2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	1*
P-UDD2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	1*
P-SCC2/3	N	N	N	Y	N	Y	N	Y	Y	Y	0.5*
KETO	Y	N	N	N	N	Y	N	N	Y	N	0.3
RP	Y	N	N	Y	N	N	N	Y	Y	Y	0.5*
TEA1	Y	N	N	N	N	Y	Y	Y	Y	Y	0.6*
UDD1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	1*

[1]for definition, see appendix.
[2]number of final models (n) in which the concerned disease was significantly ($P < 0.10$) related to culling, divided by the total number of models (N=10)
[a]non significantly related to early culling in the concerned final model ($P > 0.10$)
[b]significantly related to early culling in the concerned final model ($P < 0.10$)
*significant proportion (PP) ($P < 0.10$)

Table 3. Diseases significantly related (*P* < 0.10) to late culling in each final model and proportion of models in which the corresponding disease was a risk factor.

Disease[1]	Sample										Proportion
	1	2	3	4	5	6	7	8	9	10	PP[2]
P-ABO1	Y[a]	Y	Y	Y	Y	Y	Y	Y	Y	Y	1*
P-ACC	N[b]	Y	Y	N	N	N	N	N	Y	Y	0.4*
P-KETO	N	N	N	Y	Y	N	N	N	N	N	0.2
P-LOC	N	N	Y	N	N	N	N	N	N	N	0.1
P-MAS3	N	N	N	N	N	N	N	Y	Y	N	0.2
P-MAS5	Y	N	N	Y	N	Y	N	N	N	N	0.3
P-MET1	N	N	N	N	N	Y	N	N	N	N	0.1
P-OVA3	N	N	Y	Y	Y	N	Y	Y	Y	Y	0.7*
P-UDD2	N	N	N	N	Y	Y	N	N	N	N	0.2
P-SCC2/3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	1*
ABO1	Y	Y	Y	Y	Y	Y	N	N	Y	Y	0.8*
ABO2	Y	N	Y	Y	Y	Y	N	N	Y	Y	0.7*
ASSIST	N	Y	N	Y	N	Y	Y	Y	N	Y	0.6*
MAS1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	1*
MAS2	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	0.9*
MAS3	Y	N	N	Y	N	Y	Y	N	N	Y	0.5*
MAS5	N	N	N	N	N	Y	N	Y	N	Y	0.3
MET1	Y	Y	Y	Y	Y	N	Y	N	Y	Y	0.8*
RP	N	N	N	Y	Y	Y	N	N	N	N	0.3
TEA1	N	N	Y	N	N	N	Y	Y	N	N	0.3
SCC2/3	N	N	Y	Y	N	N	Y	N	N	N	0.3

[1]for definition, see appendix.
[2]number of final models (n) in which the concerned disease was significantly ($P < 0.10$) related to culling, divided by the total number of models (N=10)
[a]significantly related to late culling ($P < 0.10$)
[b]non significantly related to late culling ($P > 0.10$)
*significant proportion (PP) ($P < 0.10$)

Tables 4 and 5 summarize the overall 2-by-2 between-final-models comparison. The number of mismatches between models varied from 0 to 7 and from 4 to 14 for analysis ROP1 and analysis ROP2 respectively, when all diseases significantly related to culling in at least one model were taken into account. When restricting the comparison to diseases significantly associated to culling (based on PP, PP≥0.4), this number varied from 0 to 3 for analysis ROP1 and from 0 to 6 for analysis ROP2. There were large discrepancies between models, especially for models concerning late culling. The number of 2-by-2 comparisons with a percentage of mismatches over 30% was 22 (out of a total of 45) for models concerning late culling after restricting the comparison to diseases significantly associated to culling (PP≥0.4).

Table 4. Number of mismatches (number of diseases retained in one final model and not in the other one) between final models for early culling (above diagonal) and after deletion of disease not-significantly related (PP<0.4) to early culling (below diagonal). Between brackets, percentages (number of diseases retained in one final model and not in the other one, divided by the total number of diseases retained in all models) are given.

	Models									
Models	1	2	3	4	5	6	7	8	9	10
1	-	6(46)	5(38)	5(38)	5(38)	5(38)	4(31)	4(31)	4(31)	3(23)
2	2(33)	-	3(23)	5(38)	3(23)	6(46)	4(31)	6(46)	7(54)	5(38)
3	2(33)	0(0)	-	2(15)	0(0)	4(31)	1(8)	3(23)	5(38)	4(31)
4	2(33)	2(33)	2(33)	-	2(15)	3(23)	3(23)	1(8)	3(23)	2(15)
5	1(17)	0(0)	0(0)	2(33)	-	4(31)	1(8)	3(23)	5(46)	4(31)
6	1(17)	2(33)	2(33)	2(33)	2(33)	-	3(23)	3(23)	3(23)	4(31)
7	1(17)	1(17)	1(17)	3(50)	1(17)	1(17)	-	2(15)	4(31)	3(23)
8	1(17)	3(50)	3(50)	1(17)	3(50)	1(17)	0(0)	-	2(15)	1(8)
9	1(17)	3(50)	3(50)	1(17)	3(50)	1(17)	0(0)	0(0)	-	2(15)
10	1(17)	3(50)	3(50)	1(17)	3(50)	1(17)	0(0)	0(0)	0(0)	-

Table 5. Number of mismatches (number of diseases retained in one final model and not in the other one) between final models for late culling (above diagonal) and after deletion of disease not-significantly related (PP<0.4) to late culling (below diagonal). Between brackets, percentages (number of diseases retained in one final model and not in the other one, divided by the total number of diseases retained in all models) are given.

	Models									
Models	1	2	3	4	5	6	7	8	9	10
1	-	5(24)	7(33)	6(29)	6(29)	7(33)	7(33)	10(48)	5(24)	5(24)
2	4(36)	-	5(24)	8(38)	7(33)	10(48)	6(29)	7(33)	4(19)	4(19)
3	3(27)	3(27)	-	8(38)	7(33)	14(67)	6(29)	9(43)	4(19)	6(29)
4	2(18)	4(36)	3(27)	-	5(24)	8(48)	6(29)	11(52)	8(38)	6(29)
5	2(18)	4(36)	1(9)	2(18)	-	9(43)	9(43)	10(48)	5(24)	7(33)
6	3(27)	5(45)	6(54)	3(27)	5(45)	-	12(57)	11(52)	12(57)	8(38)
7	4(36)	4(36)	5(45)	2(18)	4(36)	5(45)	-	5(24)	8(38)	6(29)
8	6(54)	4(36)	5(45)	4(36)	4(36)	5(45)	2(18)	-	7(33)	7(33)
9	3(27)	3(27)	0(0)	3(27)	1(9)	6(54)	5(45)	5(45)	-	4(19)
10	3(27)	3(27)	2(18)	3(27)	3(27)	4(36)	3(27)	5(45)	2(18)	-

Health disorders as ROP-level risk factors for culling

Tables 6 and 7 give the descriptive statistics of the logistic regression coefficients corresponding to diseases significantly associated to culling, i.e. PP is at least equal to 0.4.

2063 cows were considered in analysis ROP1. The number of pairs of lactations ending by an early culling ranged from 95 to 109 (mean=103.2). 3 health disorders from the previous lactation (P-TEA2, P-UDD2, P-SCC3) showed a positive association with early culling. A cow with TEA1, UDD1 had a significantly higher risk of being culled, in comparison to cows without these disease. There was a negative relationship between RP and culling. Estimates of regression coefficients showed large variations.

Table 6. Regression coefficients and their standard errors corresponding to diseases significantly related to early culling in analysis ROP1 (2063 cows - based on PP) and analysis AP1 (3223 pairs of lactations)

Disease[1]	Analysis ROP1 Regression coefficient (β) mean	minimum	maximum	Standard error of the mean of β	PP[2]	Analysis AP1 Regression coefficient	Standard error
P-TEA2	1.81	1.35	2.35	0.10	1	1.29	0.55
P-UDD2	1.50	1.33	1.80	0.06	1	1.26	0.56
P-SCC3	0.68	0.56	0.80	0.04	0.5	0.63	0.24
KETO	-	-	-	-	0.3	0.91	0.36
RP	-0.80	-0.97	-0.63	0.06	0.5	-	-
TEA1	1.10	0.96	1.23	0.04	0.6	1.52	0.50
UDD1	1.45	0.96	1.86	0.09	1	1.19	0.44

[1]for definition, see appendix.
[2]PP: number of final models (n) in which the concerned disease was significantly ($P < 0.10$) related to culling, divided by the total number of models (N=10).

1988 cows were considered in analysis ROP2. The number of pairs of lactations that ended by a late culling ranged from 759 to 791 (mean=780.2). 5 health disorders from the previous lactation were significantly associated to late culling. Cows experiencing abortion (P-ABO1), accident (P-ACC), P-SCC2 and P-SCC3 had a higher risk of being culled than cows without these disorders. In contrast, cystic ovaries (P-OVA3) were protective for culling in the subsequent lactation. 7 health disorders (ABO1, ABO2, ASSIST, MAS1, MAS2, MAS3, MET1) were positively associated to culling as direct effects. Estimates of regression coefficients showed large variations.

Table 7. Regression coefficients and their standard errors corresponding to disease significantly related to late culling in analysis ROP2 (1988 cows - based on PP) and analysis AP2 (3058 pairs of lactations)

Disease[1]	Analysis ROP2 Regression coefficient (β) mean	minimum	maximum	Standard error of the mean of β	PP[2]	Analysis AP2 Regression coefficient	Standard error
P-ABO1	2.17	1.72	3.0	0.13	1	1.85	0.74
P-ACC	0.91	0.76	1.10	0.08	0.4	0.67	0.37
P-OVA3	-2.07	-2.47	-1.75	0.10	0.7	-1.80	0.94
P-SSC2	0.25	0.16	0.43	0.03	1	0.30	0.11
P-SSC3	0.50	0.36	0.67	0.03	1	0.54	0.14
ABO1	1.37	0.97	1.70	0.09	0.8	1.25	0.52
ABO2	1.25	0.87	1.77	0.13	0.7	1.16	0.39
ASSIST	0.48	0.44	0.61	0.02	0.6	0.41	0.19
MAS1	0.41	0.28	0.50	0.02	1	0.49	0.14
MAS2	0.54	0.39	0.73	0.04	0.9	0.50	0.18
MAS3	0.47	0.40	0.58	0.03	0.5	0.38	0.17
MET1	0.51	0.40	0.68	0.03	0.8	0.55	0.18
SCC2	-	-	-	-	0.3	-0.25	0.11
SCC3	-	-	-	-	0.3	-0.29	0.14

[1]for definition, see appendix.
[2]PP: number of final models (n) in which the concerned disease was significantly ($P < 0.10$) related to culling, divided by the total number of models (N=10).

ROP analyses versus AP analyses

General trends in the relationship between each health disorder and culling can be assessed by comparing outcomes of analyses AP1 and AP2 to those of analyses ROP1 and ROP2 (Tables 6 and 7). No discrepancies can be noticed in the direction of the relationship, since each disease was either a risk indicator or a protective indicator in both analyses. However, the magnitude of the relationship showed variations. 3 (out of 5) and 9 (out of 12) regression coefficients estimated at AP-level were included in the range (minimum-maximum) of the ß for early culling and late culling analyses at the ROP-level respectively.

DISCUSSION

A straightforward analysis of binary data originating from clustered observations is a well recognized problem in epidemiological studies. In the present study, clustering occurred at 2 levels: cows were clustered within herds and pairs of lactations were clustered within cows. The first clustering can be taken into account by using random effect models with herd as main plot (McDermott et al., 1994). A similar adjustment for within-cow clustering is much more difficult for two reasons. First, no commercial software was available to take into account simultaneously random effects at two levels (herd and cow). Secondly, using cow as a main plot would result in a large number of main plots (as in most epidemiological studies) and consequently in an extraordinary amount of computing time. Therefore, the analysis should be done at the cow level adjusting for herd effect. Then, the strategy might be to use all cow information (all pairs of lactations, leading to biased results) or to choose randomly one pair of lactations (leading to loss of information). An example of random selection of cows in epidemiological studies is Bigras-Poulin (1985). However, random selection induces variability due to sampling error (Martin et al., 1987) and therefore, the outcomes of the analysis might vary from one sample to another. This variation might be qualitative, meaning that some parameters do not appear to be significant in all final models, and/or quantitative, meaning that the estimated coefficients of significant parameters vary between analyses.

In contrast to Bigras-Poulin (1985), 10 random samplings were done in the present study to assess the variability of outcomes. Thus, performing 10 random selections appeared to be a compromise between the choice of the procedure and the resulting time computing. This procedure was also deemed relevant, considering the number of possible pairs of lactations available per cow, in order to keep as much information as possible from the native dataset. The probability for a pair of lactation not to be used in any model is below 0.001 for cows with three lactations available, and below 0.02 for cows with four lactations available.

From a mathematical point of view, the means of the regression coefficients can not be exponentiated to obtain odds ratios and confidence intervals associated with covariates. Nevertheless, both the descriptive statistics and the proportion of each risk factor provide useful information concerning the relationship between the risk factor and the outcome.

In the present study, the overlap between the 10 samples was considerable because 1016 (out of 2063) cows only experienced 2 consecutive lactations during the study period and by that were forced into each sample. Despite this, the between-samples comparison showed both qualitative and quantitative variations. This variation was not reduced after exclusion of the parameters that were not significant based on the proportion PP. Using a single random sample might give incomplete information and by that the understanding of the studied process will be suboptimal (Tables 2 and 3).

The overall agreement in results when accounting or not for dependency of observations stresses the fact that ignoring the within-cow-dependency of lactations did not lead in large bias in computed solutions in the present study. However, some qualitative differences can be pointed out. RP is significantly associated to early culling in analysis ROP1 and not in analysis AP1. By contrast, KETO and SCC2 and SCC3 are significantly related to culling at the all pairs of lactations-level and not at the random one pair of lactations-level. Some hypotheses can be stated for these differences. First, that could be explained by heterogeneity of incidence of diseases between the three subpopulations of cows, i. e. cows with 2, 3 and 4 lactations available respectively. The chance of being significant for a more (respectively less) frequent disease in cows with only two lactations is larger (respectively lower) in that case. A way for correcting such bias could be to apply a same selection rate in the three subpopulations, but that implies a loss of information and then a loss of power. However, when health disorders are equally distributed, maintaining the power as large as possible is worthwhile. Furthermore, for disease with low prevalence (e. g. KETO), the power is more sensitive to sample size. Excluding some lactations may decrease the power of each modelling. Furthermore, the range of the regression coefficients support the relevancy of repeated random selections for a more accurate description of the relationships between health disorders and culling.

Repeated sampling before modelling, although very simple in its principles, has the obvious drawback to imply a huge computing time, given repeated analyses. However, increasing the number of analyses (N) performed is a necessary condition to provide a more accurate identification of potential risk factors and assessment of the regression coefficients attached to them. It may be used when accounting for two levels of nested effects in multiple logistic regression analyses is necessary.

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APPENDIX

Description of disease, reproductive and milk production variables taken into account in the analysis 1 and in the analysis 2

Abbreviation: Current lactation	Abbreviation: Previous lactation	Definition
Reproductive performance and milk production variables		
REPRO[1]	P-REPRO	reproductive index at 110 days post-partum
START[1]	P-START[2]	best of the two first milk records (kg)
305MP[2]	P-305MP	305-day milk production (kg)
BVM	-	breeding value for milk (kg)
Disease variables[3]		
ABO1[1]	P-ABO1	abortion from 100 to 180 days of gestation
ABO2[1]	P-ABO2	abortion at more than 180 days of gestation
ACC	P-ACC	accident, trauma, haemorrhage of genital tractus, embryotomy, caesarean section, leg paralysis diagnosed at 10 days or less post-partum
ASSIST	P-ASSIST	dystocia: calving provided with assistance
DIG[1]	P-DIG	miscelleanous digestive disorders
KETO	P-KETO	ketosis or loss of appetite without any concurrent health disorders within a [-3,+3] days interval, diagnosed at 45 days or less post-partum
LOC[1]	P-LOC	foot and legs disorders
MAS1	P-MAS1	mastitis diagnosis at 45 days or less post-partum
MAS2[1]	P-MAS2	mastitis diagnosed from 46 to 90 days post-partum
MAS3[1]	P-MAS3	mastitis diagnosed from 91 to 180 days post-partum
MAS4[1]	P-MAS4	mastitis diagnosed from 181 to 270 days post-partum
MAS5[1]	P-MAS5	mastitis diagnosed at 271 days or more post-partum
MASD[2]	P-MASD	mastitis diagnosed within the dry period
MET1	P-MET1	vaginitis, vulvitis, vulvo-vaginitis, endometritis, metritis, pyometritis diagnosed at 21 days or less post-partum
MET2[1]	P-MET2	vaginitis, vulvitis, vulvo-vaginitis, endometritis, metritis, pyometritis diagnosed from 22 to 49 days post-partum
MET3[1]	P-MET3	vaginitis, vulvitis, vulvo-vaginitis, endometritis, metritis, pyometritis diagnosed at 50 days or more post-partum
MF	P-MF	milk fever
OVA1[1]	P-OVA1	cystic ovaries diagnosed from 46 to 90 days post-partum
OVA2[1]	P-OVA2	cystic ovaries diagnosed from 91 to 150 days post-partum
OVA3[1]	P-OVA3	cystic ovaries diagnosed at 151 days or more post-partum
RES1[1]	P-RES1	respiratory disorders diagnosed at 150 days or less post-partum
RES2[1]	P-RES2	respiratory disorders diagnosed at 151 days or more post-partum
RP	P-RP	retained placenta (>12 hours)
SCC[1]	P-SCC	milk somatic cell count status (SCC1: healthy, SSC2: doubtful, SCC3: infected)
TEA1	P-TEA1	teat injuries and trauma diagnosed at 45 days or less post-partum
TEA2[1]	P-TEA2	teat injuries and trauma diagnosed at 46 days or more post-partum
UDD1	P-UDD1	non traumatic udder disorders diagnosed at 45 days or less post-partum
UDD2[1]	P-UDD2	non traumatic udder disorders diagnosed at 46 days or more post-partum

[1]not used in analysis 1
[2]not used in both analyses 1 and 2
[3]for each variable, the cow was positive when the event occurred at least once.

CHAPTER 5

EFFECT OF DISEASE ON LENGTH OF PRODUCTIVE LIFE OF FRENCH HOLSTEIN DAIRY COWS ASSESSED BY SURVIVAL ANALYSIS

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EFFECT OF DISEASE ON LENGTH OF PRODUCTIVE LIFE OF FRENCH HOLSTEIN DAIRY COWS ASSESSED BY SURVIVAL ANALYSIS

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ABSTRACT

Data from a survey, performed from 1986 to 1990, were analyzed to assess the effects of diseases on length of productive life of 3589 Holstein cows from 47 herds, using a proportional hazard model.

The probability of a cow being culled, or hazard function, was supposed to be the product of an unspecified baseline hazard function and log-linear time-dependent explanatory variables possibly influencing culling rate (Cox's regression). The effect of 16 health events was studied according to lactation number of occurrence. The model included adjustments for effects of herd-year-season (considered to be random), month of calving, stage of lactation, lactation number, reproductive performance, and milk production.

The probability of being culled increased in early and late stages of lactation, in older cows, in low producing cows, in cows with poor reproductive performances. Mastitis before the peak of lactation or during the dry period increased the risk (relative culling rate in first lactation: 1.3 and 4.0, respectively). Teat injuries and nontraumatic udder disorders had a large impact on longevity. Cows with late metritis or early abortion had poor survival. The decrease in median length of productive life could be over a standard lactation in particular cases.

Expected survivor curves, computed after a priori values of covariates and their evolution over time were assumed, appear to be powerful tools for examining the effect of health disorders on length of productive life of cows.

Key words: longevity, disease, survival analysis

INTRODUCTION

Longevity is highly related to farm profit. Decisions to replace cows are mainly based on economic considerations; i.e., the farmer expects a higher profit by replacing the cow than by keeping her in the herd (van Arendonk, 1988). As a result of milk production quotas, reduction of production costs can allow profitability of dairy farms to be maintained. Thus, more attention is now given to health management in order to minimize losses that are due to health disorders. Losses caused by health disorders in dairy herds were estimated to be > \$100/yr per cow (Dijkhuizen, 1983; Sischo et al., 1990). The contribution of cullings to disease-related losses can be high. In many cases, involuntary cullings are related to health disorders. Rogers et al. (1988) and van Arendonk (1986) showed that a decrease in involuntary cullings allows an increase in voluntary culling and a higher farm profit.

Most epidemiological studies investigating the relationships between diseases and culling were performed using standard regression techniques (logistic regression, discriminant analyses). By means of such techniques, the relationships between diseases and culling were assessed in terms of risk, but not in terms of impact on longevity. Furthermore, most studies were performed without consideration of the time of culling within the lactation or the time of occurrence of the diseases. Therefore, the exact time of follow-up of health disorders was not considered.

Length of productive life (LPL), defined as the number of days between date of first calving and date at culling or death, has been used as a suitable measure of longevity (Ducrocq et al., 1988). Measures of longevity such as LPL are always characterized by presence of incomplete records, because some cows are still alive at the end of the study period. These cows generate censored data, for which only the lower bound of their LPL is known. The proportional hazard model (Cox, 1972; Kalbfleisch and Prentice, 1980), developed as a suitable method to analyse censored records, is based on the concept of hazard, defined as the probability of being culled at time t, given that the animal is still alive just prior to t. With survival analysis techniques, the probability of culling is assessed for each consecutive day of life, and information from censored observations can be used. Furthermore, some cows can enter the study period after their first calving, and then the lower bound of their LPL is not known. Information from these cows, generating left-truncated records, can also be analysed using such a model. Additionally, Kalbfleisch and Prentice (1980) showed that the proportional hazard model can be extended to cases for which variables are time-dependent. With the introduction of time-dependent variables, the assumption of proportional hazards throughout the lifespan of cows is more easily verified. Therefore, such an approach, for which health disorders are introduced as time-dependent variables, appears to be powerful to investigate the impact of disease on longevity.

Two types of longevity were defined by Ducrocq et al. (1988). True longevity is the longevity as actually observed. Functional longevity is the aptitude to delay involuntary culling, mainly because of health disorders (mastitis, lameness, and reproductive health disorders). In preventive medicine, study of functional longevity could provide information and criteria for the prediction of lifespan of dairy cows to be accounted for in herd health programs.

Analyses of survival data of dairy cows have been performed by breeders mostly to estimate genetic parameters of stayability (Smith and Quaas, 1984; Smith and Allaire, 1986; Ducrocq et al., 1988; Ducrocq, 1994). Few epidemiological studies were performed using life data methods. Curtis et al. (1989) and Waltner-Toews et al. (1986) studied survival of calves, Lee et al. (1989) the effect of diseases on days open, and Thomsen et al. (1992) the risk factors for infections in Danish swine herds. Such methods were also used for studying survival of dairy cows, but only as secondary objective (Cobo-Abreu et al., 1979; Dohoo and Martin, 1984; Thysen et al., 1988; Tranter and Morris, 1991; Barkema et al., 1992).

The objective of this study was to assess the effects of the main health disorders on LPL of dairy cows using a proportional hazard model.

MATERIALS AND METHODS

Study Population

A prospective longitudinal survey was conducted in 47 commercial Holstein herds located in western France. Data were collected between February 1, 1986 and June 30, 1990. To participate, herds had to be of the Holstein breed and enrolled in a milk production recording program, and cows had to be bred primarily by AI. Data concerning disease occurrences were from records routinely collected by farmers and veterinarians. Each herd was visited approximately at 6 wk intervals by a trained technician, who collected individual demographic data concerning new calvings, cullings, and disease occurrences recorded since the previous visit. The monthly milk production records were obtained directly from the milk recording association. Collection, storage, and validation of data were described previously (Beaudeau et al., 1994).

Model

The model used was based on the concept of hazard function $\lambda(t)$, where $\lambda(t)$ is the probability for a cow of being culled at t, given that the cow is alive just prior to t. This hazard characterizes the relative risk of being culled. A proportional hazard model, also known as a Cox regression model, was used. The hazard rate $\lambda(t) = \lambda(t,z_i(t))$ is the product of a baseline hazard function $\lambda_0(t)$, representing the aging process, and of a term $e^{z_i\beta}$, representing the vectors of covariates that influence culling rate with time. The effects of these variables can be estimated independently from the baseline hazard function with a semi-parametric estimation procedure (Cox, 1972; Kalbfleisch and Prentice, 1980), which involves the maximization of a partial likelihood. The baseline hazard function can then be arbitrarily defined.

The model considered can be written as

$$\lambda(t) = \lambda(t,z_1(t),z_2(t)) = \lambda_0(t) \exp \{ \Sigma z_1(t) + \Sigma z_2(t) \}$$

where $\lambda(t)$ is the hazard function at time t; $\lambda_0(t)$ is the unspecified hazard function; $z_1(t)$ describes the effect of covariates other than health disorders that influence culling risk; and $z_2(t)$ describes the effect of health disorders that possibly influence LPL of cows.

The observations analyzed were LPL defined as the number of days between first calving and exit from the herd. The exit from the herd could be by culling (including sales) or death. The culling date was defined as the date of actual exit from the herd. If the cow was alive at the end of the study, the record was considered to be censored at that date.

The dependent covariates other than health disorders ($z_1(t)$) that possibly influence the hazard of a cow were herd-year-season, month of calving, parity, stage of lactation, score for milk production (MP), score for fat content of milk (FC), score for protein content of milk (PC), and reproductive status (Ducrocq et al., 1988; Beaudeau et al., 1994; Ducrocq, 1994).

The inclusion of the effect of herd-year-season was included to account for differences in culling policies among herds and over time and was assumed to be a piecewise constant random effect with jumps, (i.e., changes), at April 1 and October 1: 300 herd-year-season effects were thus defined. Effects of herd-year-season were defined as random by Ducrocq (1994) in order to decrease the sensitivity of the estimates of these effects to the number of actual failures observed in each herd-year-season group (Ducrocq et al., 1988). The effects were assumed to be independently and normally distributed; the mean was 0, and the variance roughly estimated in a preliminary analysis at 0.5 on the log-scale. Sensitivity of the results to the variance component was investigated.

Month of calving and parity (treated as a discrete variable with seven classes: 1, 2, 3, 4, 5, 6, and ≥ 7) were assumed to be piecewise constant; jumps occurred at date of calving. The effect of stage of lactation was assumed to be piecewise constant; jumps occurred at 0, 60, 150, and 270 d postpartum of each lactation.

The MP, FC, and PC were defined as continuous variables in order to retain as much information as possible.

The MP was intended to account for the culling because of low milk production and hence to approximate functional longevity better. To limit a possible confusion that was due to effect of diseases on cumulative milk production, MP was built on the concept of potential milk production, calculated from the milk yield at the peak of lactation, with the assumption that this yield was affected to a lesser extent by occurrences of most diseases. Additionally, this potential was supposed to be known by the farmers on the basis of the highest milk yield record of the cow and, consequently, had no possibility of decrease throughout the cow's life. The MP was built based on four steps. A potential 305-d mature equivalent milk production (P305ME) was calculated by extrapolation of the best of the first two monthly milk yield records. Cows were then sorted within herd-year of calving, based on potential 305-d mature equivalent milk production (P305ME) and 305-d mature equivalent milk production (305ME). Based on their rank within herd-year of calving and separately for first and later lactations, an expected normal score was calculated for potential 305-d mature equivalent milk production (S-P305ME) and 305-d mature equivalent milk production (S-305ME), respectively, for each lactation.

For a cow with n lactations (from 1 to n), scores assigned to MP were, respectively,

starting at date of calving of lactation 1,	$S\text{-}P305ME_1$;
starting at date of calving of lactation n,	$\max(S\text{-}P305ME_{n-1};S\text{-}305ME_{n-1})$ for n from 2 to n;
starting at date of second monthly record,	$\max(S\text{-}P305ME_{n-1};S\text{-}305ME_{n-1};$ $S\text{-}P305ME_n)$ for n from 2 to n.

The MP was a continuous time-dependent variable considered to be a piecewise constant effect; jumps occurred at times corresponding to increases in $S\text{-}P305ME_n$ or $S\text{-}305ME_n$ for all lactations numbered from 1 to n.

For building FC and PC, lactations were sorted based on 305-d mature equivalent fat content and 305-d mature equivalent protein content separately. Based on the cow's rank within herd-year of calving and separately for first and later lactations, an expected normal score was calculated for each lactation for 305-d mature equivalent fat content and for 305-d mature equivalent protein content. The FC and PC were continuous time-dependent variables considered to be piecewise constant effects; jumps occurred at the beginning of each lactation.

Reproductive status was defined in four ordinal classes of values of days open postpartum. When the status of a cow was switched from one class to the next, the cow was supposed to be affected by more severe fertility problems. This variable was a time-dependent variable, and its effect was a piecewise constant effect; jumps occurred at date of calving and at the first date of any recorded AI occurring within the intervals 90 to 149, 150 to 209, and ≥ 210 d postpartum of each lactation. Lactations 1, 2 and ≥ 3 were considered separately in definition of this variable. Hence, 12 classes of reproductive status x lactation number were defined.

The vector $z_2(t)$ described whether the cow was exposed or unexposed at a given time to each of 16 health disorders: late abortion, calving ease, milk fever, retained placenta, early metritis, late metritis, early abortion, cystic ovaries, mastitis, teat injury, nontraumatic udder disorders (nodes, cracks, edema or bloody milk), milk SCC, ketosis, and digestive, locomotor, and respiratory disorders. Table 1 details the definition of the effects of health disorders introduced in the models. Clinical diseases were defined as time-dependent variables, and their effect on the hazard was assumed to be piecewise constant within lactation; jumps occurred at date of first occurrence. The hazard corresponding to the absence of disease was assumed at each date of calving, and diseases were assumed to influence hazard from the date of their first occurrence onward in the current lactation. The effect of monthly milk SCC was assumed to be piecewise constant; jumps occurred at date of change with regard to three classes of values: < 300,000 cells/ml (class 1), 300,000 to 800,000 cells/ml (class 2), and > 800,000 cells/ml (class 3) (Serieys, 1985). No change from class 3 to another class occurred when a monthly milk SCC record of class 3 was not followed by two consecutive monthly records of class 1. The hypothesis was that, at the date of a new monthly record, the farmer considered a cow to be previously infected (in class 3) at least once more, regardless of her current status. The effects of clinical diseases were assessed depending on the lactation number of occurrence, when the incidence in each cell was considered to be sufficient (≥ 10 uncensored cases). Farmers probably did not make the same decisions when they had to face health problems in primiparous cows than when the similar problems occurred in multiparous cows. Therefore, all health events, except late abortion, early abortion, locomotor disorders, milk fever, mastitis, and teat injuries, were considered to be different in lactations 1, 2 and ≥ 3. The impact of late abortion and early abortion was assessed regardless of the lactation number. The impact of locomotor disorders, milk fever, mastitis, teat injuries was assessed in lactations 1 and ≥ 2. Rowlands et al. (1986) showed that mastitis, lameness, and hypocalcemia were recurrent over lactations. Therefore, the possible existence of a similar event in the previous lactation was accounted for in the definition of mastitis, milk fever and locomotor disorders in the lactations ≥ 2. Thus, cases with or without occurrence of at least one episode in the previous lactation or with unknown occurrence in the previous lactation (for left-truncated records) were considered separately.

Table 1. Description of health disorders taken into account in the analyses.

Definition of diseases and of their effects	Number of levels[2]	Comments[3]
Late abortion inducing a new lactation abortion from 181 to 265 d of gestation	2	Considered whatever the lactation number
Calving ease Calving provided with assistance; Accident, trauma, haemorrhage of genital tractus, embryotomy, caesarean section, leg paralysis diagnosed at ≤ 10 d pp[1].	7	
Milk fever	8	Considered in lactation 1; ≥2; considered separately for "with-/without/unknown" occurrence in previous lactation from lactation number ≥ 2
Retained placenta (>12 h)	4	
Ketosis or loss of appetite diagnosed at ≤ 45 d pp	4	
Miscelleanous digestive disorders	4	
Miscelleanous respiratory disorders	4	
Early metritis vulvitis, vulvovaginitis, endo-metritis,vaginal discharge, metritis, pyometritis diagnosed from 22 to 49 d pp	4	
Late metritis vulvitis, vulvovaginitis, endometritis, vaginal discharge, metritis, pyometritis diagnosed at ≥ 50 d pp	4	
Early abortion abortion from 100 to 180 d of gestation	2	Considered whatever the lactation number
Cystic ovaries diagnosed at ≥ 46 d pp	4	
Locomotor disorders Diagnosed at ≤ 60 d pp; Diagnosed from 61 to 180 d pp; Diagnosed at ≥ 181 d pp; Second case of locomotor disorders.	20	Considered in lactation 1; ≥ 2; considered separately for "with-/without/unknown" occurrence in previous lactation from lactation number ≥ 2
Mastitis Diagnosed at ≤ 45 d pp; Diagnosed from 46 to 150 d pp; Diagnosed at ≥ 151 d pp; Diagnosed during the dry period; Second case of mastitis.	24	Considered in lactation 1; ≥ 2 considered separately for "with-/without/unknown" occurrence in previous lactation from lactation number ≥ 2
Teat injuries	3	Considered in lactation 1; ≥ 2;
Nontraumatic udder disorders (nodes, cracks, bloody milk)	4	
Milk SCC status SCC record <300,000 cells/ml : class 1; SCC record from 300,000 to 800,000 cells/ml : class 2; SCC record ≥ 800,000 cells/ml : class 3.	3	No jump from class 3 occurred when a monthly SCC record of class 3 was not followed by two consecutive monthly records of class 1

[1]Pp:postpartum.
[2]The level describing absence of health disorders is included.
[3]General case: considered different in lactation 1, 2, ≥ 3.

Reproductive status described the status of the cow with regard to days open. The occurrence of reproductive health disorders is associated with increased days open (Sandals et al., 1979; Shanks et al., 1979; Oltenacu et al., 1983; Lee et al., 1989). Table 2 shows that reproductive health disorders (retained placenta, early metritis, late metritis, early abortion, and cystic ovaries) were significantly related to reproductive status in the present data; proportion of affected lactations increased when days open increased; therefore, the reproductive status and the reproductive health disorders were not included in the same model in order to avoid possible overadjustment and confounding. The impact of health disorders that were not related to reproduction on LPL was assessed using a proportional hazard model including herd, stage of lactation, lactation number, month of calving, MP, FC, PC, reproductive status, and all health disorders that were not related to reproduction. For fertility, this model was intended to investigate especially the impact of the consequences of reproductive health disorders on LPL. In order to assess the impact of reproductive health disorders on LPL, the reproductive status was excluded from the previous models, and all health disorders (related and unrelated to reproduction) were introduced. This model concerned possible biological relationships between reproductive health disorders and LPL.

Table 2. Relationships between reproductive health disorders and reproductive status (3589 cows, 7703 lactations).

		Postpartum days open				Significance[3]
Health disorder		<90 d (n = 3579)	90 to 149 d (n = 2278)	150 to 209 d (n = 1018)	≥ 210 d (n = 828)	
Retained placenta, %	Yes	8.7[1]	10.1	14	15.3	0.01
	No	91.3[2]	89.9	86	84.7	
Early metritis, %	Yes	5.2	6.9	7.8	8.1	0.1
	No	94.8	93.1	92.2	91.9	
Late metritis, %	Yes	1.4	5.8	12.6	14.1	0.01
	No	98.6	94.2	87.4	85.9	
Early abortion, %	Yes	0	0	1	4.7	0.01
	No	100	100	99	95.3	
Cystic ovaries, %	Yes	1.6	4.2	6.8	7.7	0.01
	No	98.4	95.8	93.2	92.3	

[1]Proportion of lactations with occurrence of the health disorder.
[2]Proportion of lactations with no occurrence of the health disorder.
[3]The test statistics of the hypothesis of association follows a chi-squared distribution with 3 df under the null hypothesis.

Method

Estimates of effects were obtained by maximization of the logarithm of the partial likelihood (Cox, 1972), using a FORTRAN program developed by Ducrocq and Sölkner (1994, unpublished). Standard errors were computed as the square root of diagonal elements of the inverse of the matrix of second derivatives of this partial likelihood. For both analyses, a three-stage procedure was used for estimation of the parameters.

In the first stage, only covariates other than health disorders and likely to influence the culling rate were accounted for in order to assess their impact on LPL. A proportional hazard model was considered, for which only effects of herd-year-season, stage of lactation, lactation number, month of calving, MP, FC, and PC (model [2]), and reproductive status (model [1]) were sequentially added in order to verify the significance of the contribution to each covariable to the model. The significance of the explanatory variables was tested using a likelihood ratio test for large samples: twice the change in log-likelihood induced by the introduction of a new effect is compared with a chi-squared distribution with ν degrees of freedom, where ν is the number of added estimable effects ($P < 0.10$) (Cox, 1972; Kalbfleisch and Prentice, 1980; Ducrocq et al., 1988; Ducrocq, 1994). The contribution of the square and the cube of MP, FC, and PC was also tested in order to approximate possible nonlinear relationships.

In the second stage, the addition of each health disorder to models [1] and [2] was tested, and only health disorders that were significantly related to LPL were retained for the third stage ($P < 0.20$).

In the third stage, a complete model was built based on model [1] or [2] plus all health disorders retained after stage 2. A backward procedure based on the likelihood ratio statistic was performed until a final model was obtained with all diseases significantly associated with LPL (models [3] and [4], respectively) ($P < 0.10$).

A relative hazard ratio (HR) can be estimated for each covariate from the hazard function by taking the exponent of the estimates of effects. At each time of LPL, the HR measures the instantaneous risk of a cow being culled when exposed versus unexposed to disease. A HR of 1 indicates that the risk of culling is the same in the exposed and unexposed groups. A HR significantly higher, respectively lower, than 1 indicates that the exposed group has a higher, respectively lower, risk of culling.

Additionally, the effect of covariates on LPL can be measured by computing expected survivor curves, for instance, given the occurrence of a particular health disorder or of a combination of health disorders (Ducrocq et al., 1988; Ducrocq, 1994). The computation of these curves requires the assumption of a priori values of all covariates over time. In the present study, diseases and reproductive status were assumed to occur at the median day postpartum of occurrence. To assess the impact of diseases on LPL, a reference cow was characterized by a constant calving interval of 365 d; average MP, FC, and PC (normal scores set to 0 for all lactations); days open < 90 d postpartum; and no disease. Additionally, other criteria were computed from the expected survivor function. The decrease in median LPL and the fraction of cows alive at the end of a given lactation partly summarize differences in expected survivor curves.

RESULTS

Out of the 3589 cows considered, 1723 cows were considered to be right-censored (48%) and 1330 to be left-truncated (37%). Average LPL of right-censored cows was 959 days versus 1155 for uncensored cows. Out of the 7703 lactations available from the cows, 274 (3.6%), 214 (2.8%), 1266 (16.4%), and 5949 (77.2%) of lactations ended before 60, from 60 to 149, from 150 to 269, and after 269 d postpartum, respectively. The incidence of the 15 investigated clinical health disorders is described in Table 3.

Table 3. Incidence of the health disorders (3589 cows, 7703 lactations).

Health disorder	Incidence per lactation
Late abortion, %	2.0
Calving ease, %	9.9
Milk fever, %	7.5
Retained placenta, %	10.5
Ketosis or loss of appetite, %	3.1
Miscelleanous digestive disorders, %	4.3
Miscelleanous respiratory disorders, %	4.2
Early metritis, %	6.4
Late metritis, %	5.6
Early abortion, %	0.6
Cystic ovaries, %	3.7
Locomotor disorders diagnosed at at ≤ 60 d pp[1], %	5.0
Locomotor disorders diagnosed from 61 to 180 d pp, %	5.4
Locomotor disorders diagnosed at ≥ 181 d pp, %	4.5
Mastitis diagnosed at ≤ 45 d pp, %	11.5
Mastitis diagnosed from 46 to 150 d pp, %	8.9
Mastitis diagnosed at ≥ 151 d pp, %	5.4
Mastitis diagnosed during the dry period, %	2.6
Teat injuries, %	1.6
Nontraumatic udder disorders, %	3.2

[1]Pp:postpartum.

The status of milk SCC is described in Table 4: 49.3% of lactations had all monthly milk SCC records < 300,000 cells/ml, whereas 25% and 25.7% were characterized by at least one monthly milk SCC record between 300,000 and 800,000 cells/ml and > 800,000 cells/ml throughout lactations, respectively.

Table 4. Descriptive statistics of milk SCC status (3589 cows, 7703 lactations).

			Quartiles		
	Mean	SD	1	2	3
Interval calving, d					
class 2[1]	174	108	78	174	259
class 3[2]	158	95	78	148	230
Status, d[3]					
2	74	92	0	33	119
3	96	95	29	63	159

[1]Class 2: occurrence within lactation of a monthly milk SCC 300,000 and 800,000 cells/ml.

[2]Class 3: occurrence within lactation of a monthly milk SCC over 800,000 cells/ml.

[3]Interval within lactation between the first and the last date of consecutive monthly milk SCC records of a given class (respectively class 2 and class 3).

Likelihood Ratio Chi-Square Tests

Table 5 displays the results of the likelihood ratio tests when covariates were added sequentially. All tests for building models [1] and [2] were significant ($P < 0.0001$), except for month of calving, the impact of which on LPL was lower than that of other effects. The effects of the square and cube of MP, FC, and PC were not significant ($P > 0.10$) (not shown). These six covariates were therefore not retained in further analyses. When each of the 16 health disorders was added to model [1] or [2], 9 out of 11 and 12 out of 16 were retained, respectively. Milk fever and respiratory disorders were excluded from further analyses with model [1]. Milk fever, respiratory disorders, early metritis, and cystic ovaries were excluded from further analyses with model [2].

Table 5. Results of the likelihood ratio tests.

Effects included in the model[1]	-2 x change in log-likelihood[2]	df (v)	Significance, %[3]
H	483	300	0.01
H, ST	352	3	0.01
H, ST, LN	37	6	0.01
H, ST, LN, R	629	9	0.01
H, ST, LN, R, MO	22	11	2.50
H, ST, LN, R, MO, MP	165	1	0.01
H, ST, LN, R, MO, MP, FC	21	1	0.01
H, ST, LN, R, MO, MP, FC, PC	26	1	0.01
H, ST, LN, R, MO, MP, FC, PC, LABO	36	1	0.01
H, ST, LN, R, MO, MP, FC, PC, MAS	167	20	0.01
H, ST, LN, R, MO, MP, FC, PC, UDD	15	3	0.01
H, ST, LN, R, MO, MP, FC, PC, SCC	90	2	0.01
H, ST, LN, R, MO, MP, FC, PC, DIG	20	3	0.02
H, ST, LN, R, MO, MP, FC, PC, TEAT	24	2	0.18
H, ST, LN, R, MO, MP, FC, PC, CALV	20	6	0.26
H, ST, LN, R, MO, MP, FC, PC, LOC	33	18	1.70
H, ST, LN, R, MO, MP, FC, PC, KET	6.0	3	11.20
H, ST, LN, R, MO, MP, FC, PC, MF	7.8	7	35.00
H, ST, LN, R, MO, MP, FC, PC, RESP	2.7	3	43.00
H, ST, LN, MO, MP, FC, PC, EABO	16.7	1	0.01
H, ST, LN, MO, MP, FC, PC, LMET	9.7	3	2.00
H, ST, LN, MO, MP, FC, PC, RP	6.9	3	7.40
H, ST, LN, MO, MP, FC, PC, EMET	1.6	3	67.00
H, ST, LN, MO, MP, FC, PC, OVA	0.3	3	96.00

[1]H = herd-year-season, ST = stage of lactation, LN = lactation number, R = reproductive status, MO = month of calving, MP = score for milk production, FC = score for fat content, PC = score for protein content, LABO = late abortion, MAS = mastitis, UDD = nontraumatic udder disorders, SCC = monthly milk somatic cell counts, DIG = digestive disorders, TEAT = teat injuries, CALV = calving ease, LOC = locomotor disorders, KET = ketosis, MF = milk fever, RESP = respiratory disorders, EABO = early abortion, LMET = late metritis, RP = retained placenta, EMET = early metritis, OVA = cystic ovaries.

[2]When the last effect is included in the model.

[3]The test statistics follows a chi-squared distribution with ν df.

Effects of Covariates on LPL

The HR for different effects of herd-year-season varied approximately from $e^{-1.2} = 0.30$ to $e^{1.2} = 3.32$, where e is the exponential function; variance for herd-year-season was set to 0.5. To study the influence of the variance component on the results, the variance was decreased or increased fourfold. As a consequence, the range of HR for effects of herd-year-season varied, but the computed solutions for other covariates were similar, and significance of all likelihood ratio tests was virtually unchanged. The analyses were not sensitive to this parameter.

Figures 1 to 4 display the influence of stage of lactation, lactation number, reproductive status, and MP on LPL, based on results from model [3]. These estimates are expressed in term of HR.

Figure 1 presents the influence of the stage of lactation on LPL. A cow during the first 60 d of her lactation has a risk of being culled twice that a cow in midlactation (from 60 to 150 d postpartum). The risk of being culled increased after 150 d postpartum and with the lactation number (Figure 2). But only cows in lactation ≥ 5 had a significantly higher risk of being culled than cows in lactation 2 ($P < 0.10$). Reproductive status had a high impact on LPL, regardless of the lactation number (Figure 3). For each lactation, the HR increased when days open increased. For instance, the risk of being culled in first lactation was five times higher for a cow with days open ≥ 210 d compared with a cow with days open < 90 d. Figure 4 characterizes the influence of MP on culling. Low producing cows (in the lower 20% of each herd) were 2.2 to 2.4 times more likely to be culled than average cows. In addition, PC was significantly related to culling. Cows with low PC (in the lower 20% of the herd) were 1.5 to 1.6 times more likely to be culled than average cows. Estimates of effects attached to MP, FC, and PC were -0.39, -0.03, and -0.19, respectively.

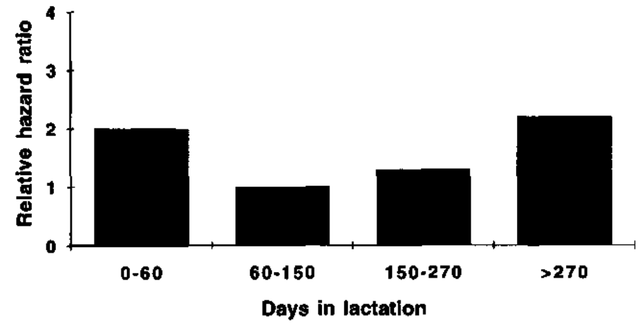

Figure 1. Estimates of the effect of stage of lactation.

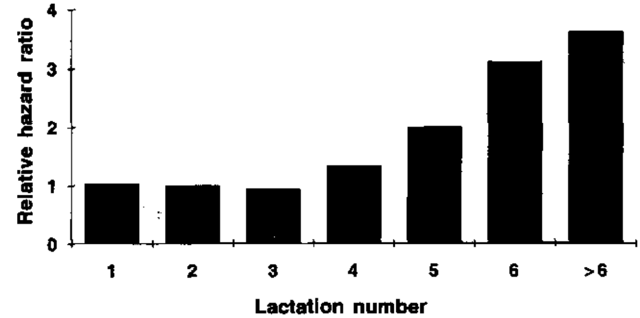

Figure 2. Estimates of the effect of lactation number.

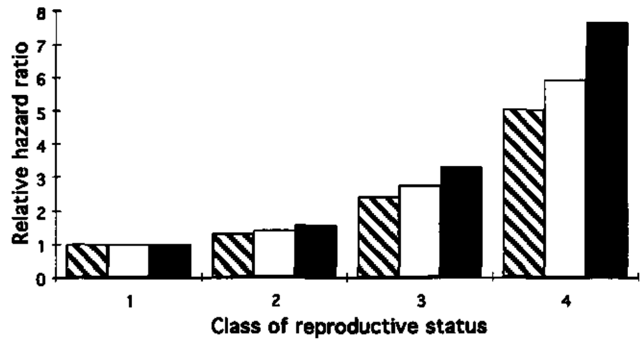

Figure 3. Estimates of the effect of the reproductive status x lactation number. Lactations 1 (hatched bar), 2 (open bar), ≥ 3 (solid bar).

Figure 4. Illustration of the effect of milk production (normal score range : -2.33 to 2.33).

When the fractions of cows alive at the end of the first and of the second lactations are calculated for cows characterized by different MP normal scores or by reproductive failures, but without any health disorder throughout their lives, the decrease was large for cows with low MP or large number of days open in first or second lactations (Table 6). However, this approach might overestimate the values attached to very low MP, because MP is likely to vary over time for a given cow. The recurrence of reproductive failure in lactations 1 and 2 often induced a further decrease in the fraction of cows alive at the end of the lactation 2.

Table 6. Illustration of the use of theoretical survivor curves to visualize the effects of level of milk production and reproductive status on LPL.

		Fraction of cows still alive at the end of	
For cows with	In lactations	Lactation 1	Lactation 2
MP[1] = -2	1 and 2	0.84	0.65
MP = -1	1 and 2	0.89	0.75
MP = 0	1 and 2	0.92	0.82
MP = 1	1 and 2	0.95	0.88
MP = 2	1 and 2	0.96	0.92
Days open			
< 90 d	1	0.92	0.82
90 to 149 d	1	0.91	0.81
150 to 209 d	1	0.87	0.75
≥ 210 d	1	0.79	0.58
Days open			
< 90 d	2	0.92	0.89
90 to 149 d	2	0.92	0.79
150 to 209 d	2	0.92	0.71
≥ 210 d	2	0.92	0.58
Days open			
90 to 149 d	1 and 2	0.91	0.78
150 to 209 d	1 and 2	0.87	0.68
≥ 210 d	1 and 2	0.79	0.53

[1]MP = Normal scores for milk production.

Table 7 displays the effect of diseases on LPL when the complete model was used. Except for mastitis after 151 d postpartum in lactation ≥ 2, and for retained placenta occurring in lactation 1, the HR, when significant ($P < 0.10$), were higher than unity. Only locomotor disorders were excluded during the backward procedure to obtain model [3].

The HR tended to increase from the effect calving provided with assistance to the effect calving accident, regardless of the lactation number (not shown). However, only calving accident in primiparous cows and both calving provided with assistance and calving accident in cows in lactation ≥ 3 were significantly ($P < 0.10$) related to an increase in HR. A cow with a late abortion was 2.4 more likely to be culled than a cow calving after a normal gestation length ($P < 0.10$). Ketosis was associated with an increased risk of being culled in lactations 1 and 2 only (HR = 1.9 and 1.7, respectively). The occurrence of digestive disorders increased the risk of being culled in lactations ≥ 3 only. Most udder health disorders were highly related to an increased risk of being culled. Mastitis occurring within 45 d or during the dry period was associated with an increased risk of culling, regardless of the lactation number. The occurrence of an episode of mastitis in the previous lactation has no significant influence on the value of the HR associated with an episode in the current lactation. Teat injuries were associated with a large risk of being culled, regardless of the lactation number, but especially during lactation 1 (HR = 5.7). A primiparous cow with nontraumatic udder disorders was 1.7 more likely to be culled than a cow without this health disorder.

Table 7. Effect of health events on length of productive life (3589 cows, 7703 lactations)[1].

Effects	Relative hazard ratio	90% CI[2]	Decrease in median longevity[3]	Fraction still alive at the end of the second lactation[4]
Model [3]				
Calving accident				
In lactation 1	1.7	1.3-2.3	58	0.78
In lactation $\geq$ 3[5]	1.7	1.2-2.5	118	0.82
Calving provided with assistance in lactation $\geq$ 3[5]	1.2	1.0-1.5	28	0.82
Late abortion[6]	2.4	1.9-3.0	284	0.70
Ketosis				
In lactation 1	1.9	1.1-3.2	67	0.77
In lactation 2	1.7	1.0-2.9	80	0.76
Digestive disorders in lactation $\geq$ 3[5]	1.9	1.5-2.4	107	0.82
Mastitis				
Diagnosed at $\leq$ 45 d pp in lactation 1	1.3	1.0-1.7	13	0.81
Diagnosed during the dry period in lactation 1	4.0	1.8-8.6	36	0.79
Diagnosed at $\leq$ 45 d pp in lactation $\geq$ 2 without any occurrence in previous lactation	1.3	1.0-1.5	13	0.80
Diagnosed at $\geq$ 151 d pp in lactation $\geq$ 2 without any occurrence in previous lactation	0.6	0.4-0.9	- 54	0.85
Diagnosed during the dry period in lactation $\geq$ 2 without any occurrence in previous lactation	8.7	5.9-12.8	443	0.65
Diagnosed at $\leq$ 45 d pp in lactation $\geq$ 2 with occurrence in previous lactation[7]	1.5	1.2-2.0	74	0.76
Diagnosed during the dry period in lactation $\geq$ 2 with occurrence in previous lactation[7]	9.4	5.5-16.1	537	0.62
Teat injury				
In lactation 1	5.7	2.8-11.7	446	0.65
In lactation $\geq$ 2	1.7	1.3-2.2	63	0.77
Nontraumatic udder disorders in lactation 1	1.7	1.2-2.4	56	0.78
SCC				
300 to 800 000 cells/ml[8]	1.2	1.1-1.4	13	0.81
$\geq$ 800 000 cells/ml[8]	1.7	1.5-2.0	64	0.78
Model [4]				
Late metritis				
In lactation 1	1.5	1.1-2.0	182	0.70
In lactation 2	1.4	1.0-2.0	239	0.69
Early abortion[9]	2.7	1.9-3.8	693	0.51
Retained placenta in lactation 1	0.7	0.6-1.0	- 36	0.78

[1]Only effects significantly related to LPL are reported ($P < 0.10$).
[2]CI = Confidence interval.
[3]In days, in comparison to cows with no health disorder, average milk production, average fat and protein contents, days open below 90 days postpartum
[4]Reference for a cow with no health disorder (model [3]) = 0.82; (model [4]) = 0.78
[5]Occurrence in lactation 3
[6]Calving inducing lactation 2
[7]With occurrence of a mastitis within 45 d postpartum in lactation 1
[8]Throughout lactation 1
[9]Occurrence in lactation 1

Monthly milk SCC records from 300,000 to 800,000 cells/ml was associated with a 1.2 times higher risk of being culled, whereas cows with monthly milk SCC records > 800,000 cells/ml had a 1.7 times higher risk of being culled, when compared with those having monthly milk SCC records < 300,000 cells/ml. No reproductive health disorder was excluded in the backward procedure for obtaining model [4]. Late metritis was associated with an increased risk of cows being culled in lactations 1 and 2 (HR = 1.5 and 1.4, respectively). A cow aborting in lactation was 2.7 more likely to be culled than a cow without that health event. A primiparous cow with retained placenta was 1.4 less likely to be culled than a cow without this event.

Measured by median longevities and expected survivor curves, the midterm impact on longevity of clinical mastitis during the lactation, nontraumatic udder disorders, high SCC and ketosis in the two first lactations seems to be low. Late metritis was associated with a decrease in median longevity > 180 d. The negative effect on median longevity and fraction of cows alive at the end of lactation 2, of mastitis during the dry period in lactation 2, teat injuries in lactation 1, and early and late abortion was particularly large. Figures 5 and 6 present an example of expected survivor curves for cows with different udder disorders in lactations 1 and 2. The midterm impact of a mastitis and nontraumatic udder disorders within 45 d postpartum (alone or combined) is low compared with the influence of teat injuries within 45 d postpartum or mastitis and teat injuries. Similarly, the additional occurrence of a mastitis within 45 d postpartum in lactation 2 did not heavily affect the risk of a cow being culled in the following lactations.

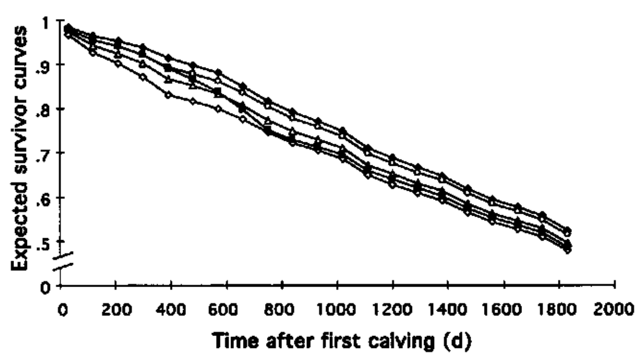

Figure 5. Expected survivor curves of five theoretical cows; (◆) without occurrence of any health disorders; (○) with occurrence of mastitis at d 3 postpartum in lactation 1; (△) with occurrence of non traumatic udder disorders at d 3 postpartum in lactation 1; (■) with occurrence of mastitis at d 3 postpartum in lactations 1 and 2; (◇) with occurrence of both mastitis at d 3 postpartum and non traumatic udder disorders at d 3 postpartum in lactation 1.

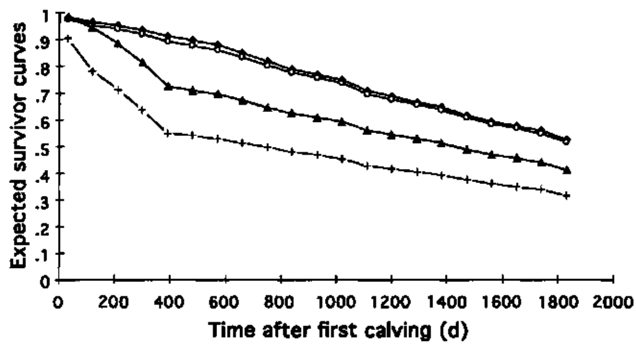

Figure 6. Expected survivor curves of four theoretical cows; (◆) without occurrence of any health disorders; (○) with occurrence of mastitis at d 3 postpartum in lactation 1; (▲) with occurrence of teat injuries at d 3 postpartum in lactation 1; (+) with occurrence of both mastitis at d 3 postpartum and teat injuries at d 3 postpartum in lactation 1.

DISCUSSION

Three measures of production were used in this study. The MP, FC, and PC effects were considered within herd-year to account for heterogeneity in culling policy between herds and over years. In contrast to results of Ducrocq et al. (1988) and Ducrocq (1994) for milk production variable, these parameters were defined as continuous variables in order to retain as much information as possible and to provide a possible higher accuracy of results. To limit a possible confusion between milk production and diseases, MP was built on the potential 305-d mature equivalent milk production. With actual production, the HR would have included a part of the impact of some diseases on culling, through their effect on cumulative milk production.

The strong relationship between reproductive health disorders and days open in the present data led us to perform two separate analyses: one including the reproductive status but not the related diseases and another one including the reproductive diseases but not the related status. This choice was intended to avoid bias that was due to overadjustment. Health disorders that were not related to reproduction were included in both analyses, despite possible interrelationships and relationships with reproductive status or other individual characteristics. The comparison of computed solutions resulting from the inclusion of each disease in models [1] or [2] with those for each disease in models [3] and [4] showed that little confounding occurred between effects: all effects were nearly additive on the hazard.

Contribution of diseases that were not related to reproduction and other individual characteristics was assessed from model [3]. From a managerial viewpoint, a priority criterion regarding health was days open, and the true impact of diseases thus had to be assessed by accounting for reproductive performances. Except for the effect of stage of lactation, the regression coefficients for each covariate included in both analyses were almost similar. Differences in estimates of the effects of stage of lactation between models [3] and [4] were due to the fact that the effect of stage of lactation included a part of the reproductive status in model [4].

Because HR measure the instantaneous relative risk of a cow being culled over time, they are the parameters most comparable with those resulting from classical regression techniques, such as odds ratios. The HR estimates constitute a comprehensive measure of effects on LPL, independently of time. Survival analysis allows the impact of health disorders on LPL to be assessed through several other criteria. Expected survivor curves are illustrations of the dynamic effect of covariates through time and result from assumptions on the occurrence of effects over time. Decrease in median longevity and fractions of cows still alive (e.g., at the end of a given lactation), which express the change in LPL at a given point of time, are time-specific. These time-dependent criteria must be interpreted in a specified situation, e.g., health disorders at median time of occurrence in a given lactation. Furthermore, decrease in median longevity depends on the duration of each effect over time. In addition to the specificity of the study population, the methods used in the present study may limit the relevancy of direct comparisons with previous studies.

Early lactation (before the peak of lactation) and end of lactation are main periods of decision making for culling, per se, especially in relation to the management of milk quotas. In contrast to results of Ducrocq et al. (1988), an early stage of lactation was associated with a higher risk of a cow being culled than midlactation. These discrepancies can be explained by differences in the study designs. Ducrocq et al. (1988) used data from the DHIA, in which cows culled before their first milk record, if culled in lactation 1, were lost, or, if culled with a higher lactation number, were considered to be culled at the end of the previous lactation. Late stages of lactation were associated with a higher risk of cows being culled in both analyses. The increased risk of culling with age was also found by Martin et al. (1982), Dohoo and Martin (1984), Bigras-Poulin (1985), and Gröhn et al. (1986), using standard regression techniques. In agreement with Erb et al. (1985) and Milian-Suazo et al. (1989), who investigated days to first AI and number of AI as risk factors for culling, respectively, the risk of cows being culled increased when days open increased, regardless of the lactation number. The high risk associated with days open ≥ 210 d, regardless of the lactation number stressed the fact that farmers probably take into account high losses caused by a too high calving interval in making culling decision, but also look for a compromise accounting for age and milk production level of the cows. Despite differences in definition of milk production variable, the detrimental impact of low milk production on LPL was also found by Ducrocq et al. (1988) and Ducrocq (1994). Similarly to Ducrocq et al. (1988), but in contrast with Ducrocq (1994), the best cows were significantly less likely to be culled than average producing cows. Accounting for the potential milk production may have led to the discrepancy with results of Ducrocq (1994).

Certain health disorders (dystocia, calving accident, mastitis, and teat injuries) increased the risk of cows being culled, in agreement with studies (Cobo-Abreu et al., 1979; Martin et al., 1982; Dohoo and Martin, 1984; Bigras-Poulin, 1985; Erb et al., 1985; Bendixen, 1988; Bendixen and Åstrand, 1989; Oltenacu et al., 1990; Barkema et al., 1992; Beaudeau et al., 1994) that used various regression methods. For others health disorders, especially reproductive health disorders (metritis, retained placenta, and cystic ovaries) and lameness, discrepancies between previous studies and the present one, in direction and in magnitude of the effects, were noteworthy.

Udder disorders and reproductive indicators appear to be key criteria in decision making for culling. All udder disorders investigated were significantly related to LPL. The high HR attached to clinical mastitis occurring before the peak of lactation or during the dry period showed that these are high risk periods for culling related to health. Despite a very low incidence, the very high risk associated with mastitis during the dry period can be explained by its severity, possibly associated with a doubt on potential yield in the next lactation. Loss in median longevity associated with the occurrence of this disorder in second lactation appears to be over a standard lactation. However, clinical mastitis after the peak or recurrence of an episode within lactation did not decrease longevity, possibly because of the lower consequences of these events on cumulative milk production given the late stage of occurrence, especially for recurrences. The high impact on LPL of teat injuries and nontraumatic udder disorders may be because they might prevent milking. The particularly high impact of these disorders when they occur in lactation 1 confirms the validity of the assumption that health events should be treated in interaction with lactation number, when possible. The occurrence of an episode of mastitis in one lactation had a low influence on the risk of culling because of an episode of mastitis in the following lactation, thus strengthening the assumption that culling is related primarily to short-term effects, rather than to the consideration of the entire disease history of the cow. Only reproductive health disorders occurring after 50 d in lactation (late metritis, early abortion) and possibly resulting in a higher impact on days open were significantly associated with a decrease in median longevity (e.g., over two-thirds of a standard lactation for late metritis in second lactation). These results agree with those concerning the impact of the reproductive status. Decrease in median longevity was much higher when calving was consecutive to a late abortion than when a calving accident occurred. When the cow recovers from a calving accident, the impact of this event is assumed to be low, whereas the influence of late abortion, often associated with a low milk production level, continues.

The fractions of cows alive at the end of the lactations 1 and 2 and the median longevities can be relevant criteria for herd health management. Decrease in longevity that is due to clinical mastitis during the lactation or high milk SCC is low; however, because of high incidence, the impact of mastitis and high SCC may be very high in some herds. Similarly, major attention must be given to late metritis, which, in addition to a high incidence, generates a theoretical loss of median lifespan over 180 d. However, despite a large negative impact on longevity, the average impact on farm profit of occurrence of teat injuries and abortion probably remains relatively low because of their low incidence.

CONCLUSIONS

The effect of diseases on the LPL of Holstein cows has been assessed using survival analysis, which is more powerful than standard regression techniques that assume that the cows are classified as culled or nonculled. Furthermore, consideration of some explanatory variables as time-dependent possibly influencing culling allows a better description of the exact follow-up of disease history of the cows, and may lead to a higher accuracy of solutions.

In addition to calving events possibly inducing urgent cullings, which had a high impact on LPL, udder disorders and reproductive disorders, mainly through poor reproductive performances, appeared to be the main health events influencing LPL. Health disorders occurring in lactation 1 have a high impact on longevity, especially in the first few months following occurrence. Generally, the impact of health disorders was lower than the contribution of reproductive performances and MP to the change in LPL of cows. Economic considerations are thus key criteria in the farmers' culling decisions. The farmer's objective is mainly to minimize losses that are due to longer calving interval and lower milk production level.

Survival analysis techniques offer farmers intuitive tools to predict LPL, which may help them make culling decisions. Furthermore, this method appears to be a desirable technique for analyses of culling decisions. It provides time-specific probabilities of culling for health disorders that could be used in models for decision and herd simulation that account for occurrence of health events. These probabilities could constitute relevant criteria to help calculate marginal costs at each day of cow life lost, by the occurrence of health disorders, compared with that of a healthy cow. Further research is needed to investigate the economic impact of diseases through changes in expected longevity, and consequently, to compare the profitability of different rules for culling decision with regard to health.

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CHAPTER 6

RELATIONSHIPS BETWEEN CULLING DECISIONS IN DAIRY HERDS AND FARMERS' MANAGEMENT STYLES

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RELATIONSHIPS BETWEEN CULLING DECISIONS IN DAIRY HERDS AND FARMERS' MANAGEMENT STYLES

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ABSTRACT

A survey was carried out in 67 dairy farms from western France to assess the relationships between culling decisions in dairy herds and farmers' management styles. The dairy farmers from three administrative districts were interviewed in a semi-direct way to collect (1) their points of view regarding culling and related topics (genetics, reproduction, quotas and health management), (2) their relationships with other farmers and external advisors, (3) their socio-demographic characteristics, (4) characteristics of the production system. A farmer's social status was defined by descriptors of the nature and the frequency of relationships a farmer had with other professionals. Farmers' points of view were classified into categories, namely, objectives, motivations, factors of context, culling decisions, modifying practices and adaptations towards culling. The farmers' management styles were defined as specific combinations of objectives, motivations and factors of context. Cluster analysis was used to identify groups of farmers sharing same criteria for culling decisions. The relationships between these clusters and farmers' management styles, production systems and sociological variables were assessed.

Five groups of dairy farmers, namely the multi-criteria conventionals, the passive traditionals, the activists, the tolerant voluntarists, and the silent traditionals, were differentiated by their criteria of culling decisions. These groups were also differentiated by their management style and social status. Culling decisions were sociologically structured and regulated. The relationships between the clusters and the production systems variables were low. Because farmers' management styles appear to modulate management practices, it could be useful to assess how farmers combine their goals, strategies, and related practices when providing tools for improving farm performances.

Key words: dairy cows, culling, management styles

INTRODUCTION

During the last decades, emphasis was put to provide farmers with tools for controlling, planning, and also improving herd and farm performances. Variations of farm performances are not only due to differences in farm characteristics (land, scale of operation, financial inputs), but can also result from differences in management practices, and human factors (Muggen, 1969; van der Ploeg, 1990). Most of the studies dealing with the relationships between management practices and herd performances (e.g., Dohoo et al., 1984; Goodger et al., 1988; Cowen et al., 1989; Faye, 1991) did not account for human factors. Thus, the assumption that these management practices were finally the result of a dynamic selection procedure from the farmers themselves, and that their own perception may greatly influence this process of adoption was not studied in such studies. However, some assumed that the farmers, in addition to the management practices used, could contribute to the variations in farm performance (Bigras-Poulin et al., 1985a,b; Hubble and Bardsley, 1986; Tarabla and Dodd, 1990; Griffin et al., 1993).

In dairy herds, the culling rate varies within herd between years (Cobo-Abreu et al., 1979; Sol et al., 1984), but also between herds (Beaudeau et al., 1994). The complexity of culling and replacement decisions, which involve many factors, could explain these variations. Many individual factors, such as age, stage of lactation, level of milk production, health status, reproductive performance, are accounted for by farmers when making culling and replacement decisions. In addition, culling is completely embedded in the whole farming process. Herd factors, such as availability of replacement heifers, milk and beef market value, replacement cost, rates of diseases, farmers' objectives regarding calving patterns, genetic improvement and quotas, may also be taken into account in the culling and replacement decisions. Following Seabrook's report that 'different stockmen achieve different results with similar resources of animals, building and feed' (Seabrook, 1984), it can be assumed that two farmers will not make at the same time the same decision regarding a cow with similar individual characteristics in a given herd. Bigras-Poulin et al. (1985b) showed that 24% of variations of culling rate were explained by variations in farmers' socio-psychological characteristics in 102 Canadian Holstein farms.

Looking to culling as activated and structured by the farmer himself may constitute a step in the understanding of variations of culling management. Culling decisions are therefore a domain of implementation of interrelated goals and motivations in a particular context of farming, also defined as management styles. A similar approach was used by van der Ploeg (1994), who showed that differential cattle-breeding strategies were related to the different management styles identified in The Netherlands (de Bruin and van der Ploeg, 1991; Roep et al., 1991).

The objectives of this study were to assess (1) how farmers combine their decisions towards culling of dairy cows, and subsequently, the extent to which these culling decisions were (2) sociologically coordinated by farmers' motivations and goals, (3) related to the farm production system and the social status of farmers involved.

MATERIAL AND METHODS

Inclusion of farms in the survey

To investigate the farmer effect on culling process, inclusion of farms in this research accounted for the GERDAL (Groupe d'Etude et de Recherche: Développement et Actions Locales) approach (Darré, 1986; Darré et al., 1989). The GERDAL assumes that the adoption of management practices results from social phenomena, in which the farmers are central actors. The technical changes and standards partly result from social interactions between farmers who share their experiences and information within their community. Then, the standards of a given farmer originate from individual choices made in a common frame, the Local Professional Group. This Local Professional Group (LPG) is defined as the group of farmers who can meet each other, and work in similar conditions (mostly approximated to an administrative district) (Darré, 1989).

In the LPG, a relational network is reconstructed, as a schedule in which each relationship a farmer has with other dairy managers and external advisors is recorded. From this network, the assessment of preferential relationships results in determining social groups within a LPG. In addition, isolated farmers (with no declared relationships with other farmers) are identified. Darré et al. (1989) showed that the morphology of the network, that is the number of social groups, the social status of farmers, and the intensity of contacts may generate local standards and influence the points of view.

A survey was carried out in the 67 dairy herds of three administrative districts (approximates to LPG) of western France. The district 1 gathered a large number of dairy farms (37), the two others (districts 2 and 3) less (18 and 12, respectively). An assumption was that the higher the density of farms within a district, the more frequent the contacts between farmers. To participate in the study, herd size had to be larger than 20 dairy cows.

Data

The social phenomena were studied based on farmers' points of view, which were assumed to originate from their goals towards farming, their own conception of farming, and also their social status within a given LPG. Farm managers were interviewed in a semi-direct way by a single investigator from July to August 1993. Telephone appointments were made a few days before interview. 93% of dairy farmers from the 3 districts were interviewed after their agreement. The mean duration of each interview was 150 min (range 90 - 240). The interview was organized in four parts. The first part ascertained the sociodemographic characteristics of farmers such as age, level of education. In a second part, the managers were asked to describe the farm's production systems through herd size, crops productions, farm status such as affiliation or not to the milk recording agency. A third part queried the farmers' points of view on culling. A pre-survey showed that culling and replacement were not subjects of discussions between farmers. Therefore, farmers were asked about topics considered to be interrelated with culling and replacement, such as genetics, reproduction, quotas management, health management. A fourth part concerned the social relationships each farmer had with other farmers and external advisors such as technicians, veterinarians, milk recording agency advisors. Data from the fourth part of the interview were used to build the social relational network corresponding to a given district and to describe the social status of each farmer. The social status of each farmer within his LPG was assessed, by description of his affiliation to a district (DISTRICT), to a social group (GROUP), his integration (INTEGRATED) (number of relationships existing with other farmers/theoretical number of relationships), his openess (OPENED) (number of relationships with external advisors) (Rogers and Kincaid, 1981), his isolation (ISOLATED) (no declared relationships with other dairy farmers). Variables resulting from parts 1, 2, and 4 are listed in Table 1.

Table 1. Description of socio-demographic characteristics, production system characteristics and personal social status (67 dairy farms from 3 districts of western France).

Variable	
Socio-demographic characteristics	
AGE	Age of the farmer (yr)
SCHOOL	No degree, Degree in agriculture
FAMILY	Married, Single
INVPRO	Investment in professional organizations (Yes, No)
INVDIST	Investment in the district associations (Yes, No)
TALK	Number of declared points of view (<6; 6 to 10; >10)
Production system characteristics	
BREED	Holstein, Other
MILK	Affiliation to the milk recording agency (Yes, No)
LAND	Total number of hectares (ha)
MAN	Average number of people working in the farm
HERDSIZE	Number of dairy cows
QUOTA	Annual quota reference
QUOTACOW	Quota reference per dairy cow
QUOTALAND	Quota reference per hectare
COWMAN	Number of dairy cows per man
LANDMAN	Number of hectares per man
CROPS	Hectares with roughages/total number of hectares (%)
CORN	Hectares with corn silage/hectares with roughages (%)
BEEF	Beef cattle in the farm (Yes, No)
CASH	% of total cash due to milk production
TAX	Low total cash (below 300 000 French francs)
Personal social status (resulting from the social relational network)	
DISTRICT	District of the farm
GROUP	Social group
ISOLATED	Farmer isolated in the district
INTEGRATED	Level of integration
OPENED	Level of openess

Method

Conceptual frame for analysing farmers' points of view

The conceptual frame of analysis, based on farmers' points of view (part 3 of the interview), is shown in Figure 1. The points of view were classified into six main groups. A first group called motivations dealt with major farmers' motivations, such as interest for milk price, carcass value, calf value and work organization. A second group of declarations concerned a draft overview of the context and some structural factors of farming, and was called factors of context. Points of views regarding strategies toward genetics, reproduction, and replacement were considered as objectives and modifying practices, because of their possible impact on declared culling decisions. The arguments related to tactical aspects were called adaptations and constituted the fourth group. The fifth group gathered the culling decisions related to selection, seasonal calvings, health, quotas management and AI rules, as declared by farmers. The sixth group gathered the outcomes resulting from culling decisions, such as culling reasons and annual numbers of cullings and replacements.

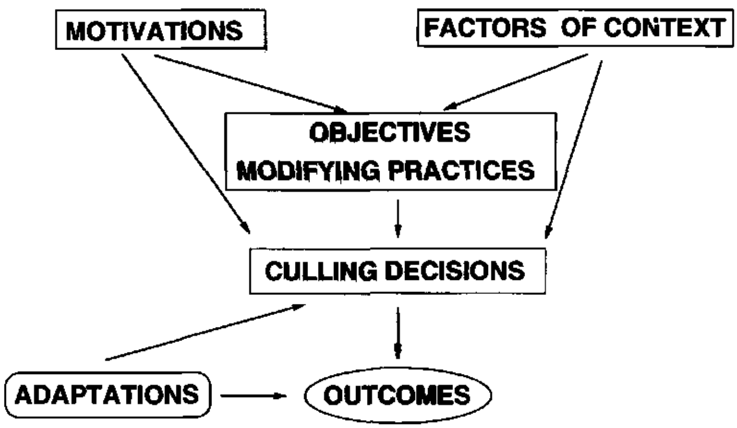

Figure 1. Conceptual frame for the analysis of farmers' points of view

Points of view classified in the groups motivations, factors of context, objectives, modifying practices, adaptations, culling decisions and outcomes are displayed in Table 2.

Some basic declarations were gathered in synthetic items (defined in capital letters in Table 2). This procedure, based on the nature of declarations, was intended to simplify information relative to a particular aspect of farming, to obtain a minimum percentage of declaration for each item (> 20 %) in the data processing together with a more general overview of the decision process. As an example, a farmer was assigned declaring SELOBJ, if he declared at least one subsequent point of view (PROTEIN, TYPE, UDDER, YIELD).

Table 2. Description of points of view and percentage of farmers who declared them (67 dairy farms from 3 districts).

Points of views Abbreviation	Definition	Frequency (%))
Motivations		
MILKP	Interest for milk price	83.6
CARCASS	Interest for carcass value	85.1
CALF	Interest for calf price	10.4
WORK	Interest for work organization	20.9
Factors of context		
QUOTA	Quota constraint	13.4
KEEP	Keeping enough cows	23.9
AI	Systematic artificial insemination	28.4
BULL	Use of a running bull	19.4
Objectives		
SELOBJ	OBJECTIVES OF SELECTION	89.6
PROTEIN	Selection for protein content	74.6
TYPE	Selection for type	47.8
UDDER	Selection for udder	22.4
YIELD	Selection for milk yield	28.4
SEASCALV	OBJECTIVE OF SEASONAL CALVING	38.8
LONGEV	OBJECTIVE OF KEEPING COWS AS LONG AS POSSIBLE	31.3
LET	LET THE NATURE DO	26.9
Modifying practices		
VOLREPL	VOLUNTARY REPLACEMENT	53.7
VOLSALE	All heifers kept at birth then surplus sold before calving	23.9
PRESS	All heifers kept at birth then pressure of heifers on culling rate	40.3
EXACT	Exact number of heifers for replacement kept at birth	22.3
PURCH	Voluntary purchase of heifers	10.4
Adaptations		
ADAPT	MEASURES REGARDING HEIFERS	31.4
INVPURCH	Extra purchase of heifers due to high culling rate	28.4
QSALE	Sale of heifers to respect quota reference	3.0
MQUOTA	OTHER MEASURES FOR QUOTAS	50.7
Culling decisions		
NODELAY	CULLING RULE TO AVOID DELAYED CALVINGS	44.8
HEALTH	CULLING RULE TO IMPROVE HERD HEALTH	71.6
SCC	Culling of cows with high milk somatic cell counts	37.3
FERT	Culling of infertile cows	20.9
AI RULES[1]		
NOL	No limit for inseminating cows	14.9
FLEX	Flexibility depending on cow's health status and milk production	59.7
AI3	Culling after 3 inseminations	25.4
CQUOTA	CULLING RULE TO RESPECT QUOTA REFERENCE	26.9
URGENT	CULLING FOR ACCIDENTS	20.9
SELECTION	CULLING FOR SELECTION	73.1
CRPROTEIN	Culling reason: low protein content	16.4
CRTYPE	Culling reason: bad type	1.5
CRUDDER	Culling reason: bad udder conformation	19.4
CRYIELD	Culling reason: low milk production level	37.3
SELYIELD	Selection of primiparous on milk yield	38.8
Outcomes		
CULLR	DECLARED CULLING REASONS	-
CULLN	DECLARED NUMBER OF CULLED COWS	-
REPLN	DECLARED NUMBER OF HEIFERS CALVING	-

[1]Exclusive modalities

The a priori classification of certain points of view in the groups objectives, modifying practices and adaptations was validated by checking, primarily, the relationships between objectives or modifying practices and culling decisions, secondly, the absence of association between adaptations and culling decisions. Tests of significance of associations between corresponding synthetic items were performed using a χ^2 test (FREQ procedure, SAS Institute Inc., 1989).

Data analyses

The analyses were carried out in 5 steps (Figure 2). In step 1, to account for the variability of the culling decisions, but also to identify groups of farmers who shared similar points of view regarding culling, culling decisions were clustered, resulting in groups of farmers handling the same set of criteria governing decisions. The relationships between these clusters and management styles, defined as specific interdependency between farmers' motivations, objectives and factors of context were assessed in step 2. The relationships between clusters of culling decisions and production systems variables and sociological variables were evaluated in steps 3 and 4 respectively. How culling decisions may affect the outcomes was investigated in step 5.

In step 1, a hierarchical agglomerative statistical technique was used to cluster the farmers according to the 6 synthetic items in the group culling decisions. A two-stage procedure was followed. In a first stage, factor analysis was performed based on these 6 items, and only factors with eigenvalues over 1 were kept for further analyses (FACTOR procedure). The culling decisions HEALTH and CQUOTA were not kept in further analyses because of their low contribution to the definition of factors (3.8 and 5.2 % of the total variance explained by factors, respectively). Factor scores of each farm were used in a second stage in the clustering procedure (CLUSTER procedure). To decide which cases should be combined at each step, Ward's clustering algorithm was chosen. The squared Euclidian distance was selected to measure the distance between cases in the cluster analysis. All the analyses were performed using the SAS software (SAS Institute Inc., 1989).

The small sample size (67) on the one hand, and the statistical changes in analyses with an increased number of clusters, such as (1) an increased distance between clusters on variables significantly different, and (2) a higher contribution of significantly different variables to the definition of clusters on the other hand led us to retain five clusters of culling decisions.

Differences among clusters for each qualitative data (motivations, factors of context, objectives, socio-demographic characteristic, social status, production system characteristics), and each quantitative variable were assessed using the FREQ and GLM procedures respectively (SAS Institute Inc., 1989). Similar analyses were performed to assess the relationships between clusters and outcomes.

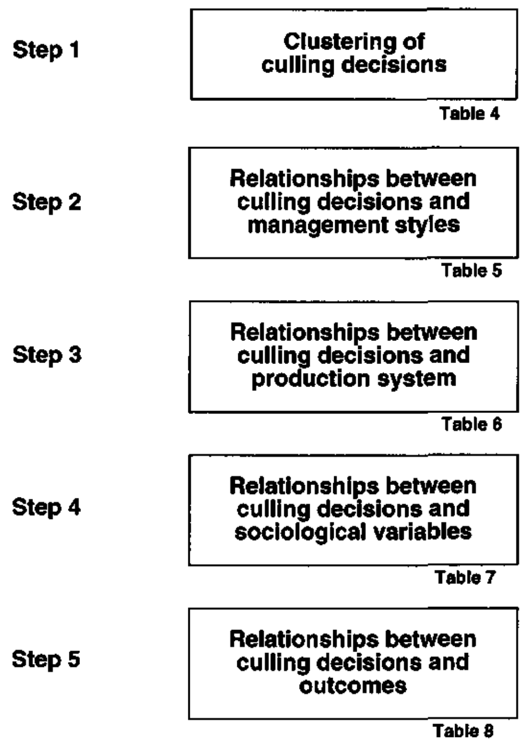

Figure 2. Steps of analysis

RESULTS AND DISCUSSION

Validation of the classification of points of view

Table 3 details the relationships between objectives and modifying practices, adaptations and culling decisions. The objectives and modifying practices were at least significantly related once to a culling decision, whereas, no adaptation had a significant association with them. These results strengthened the relevancy of this classification. Modifying practices were not associated with culling decisions regarding health, urgent culling, and culling for quotas.

Table 3. Relationships between objectives, modifying practices, adaptations and culling decisions.

	Culling decisions[1]					
	NODELAY	SELECTION	HEALTH	AI RULES	URGENT	CQUOTA
Objectives[1]						
SELOBJ	Y-Y[2] ***	Y-Y***	NS	Y-Y[2] (FLEX)[4] **	NS	NS
SEASCALV	Y-Y ***	Y-Y *	NS	Y-Y (FLEX) ***	NS	NS
LONGEV	Y-Y ***	Y-Y ***	Y-N *	Y-Y (FLEX) ***	NS	NS
LET	Y-N[3] ***	Y-N ***	NS	Y-Y[2] (NOL)[4] *	NS	NS
Modifying practices[1]						
VOLREPL	Y-Y ***	NS	NS	Y-Y[2] (IA3)[4] ***	NS	NS
Adaptations[1]						
ADAPT	NS	NS	NS	NS	NS	NS
MQUOTA	NS	NS	NS	NS	NS	NS

[1]For definition, see Table 2.
[2]Y-Y: significant positive association between the two synthetic items.
[3]Y-N: significant negative association between the two synthetic items.
[4]Significant positive association between the objective or modifying practice and the corresponding AI rule.
* $P < 0.20$; **$P < 0.10$; ***$P < 0.05$; NS: non significant ($P > 0.20$).

Relationships between clusters of culling decisions and farm and farmer characteristics (steps 1 to 5)

The proportion of variance accounted for by the 5 clusters was 77%. Table 4 shows the contribution of each culling decision to the five elaborated clusters. Table 5 displays the relationships between clusters and motivations, factors of context, objectives as declared by farmers. Tables 6, 7, and 8 shows the relationships between production system characteristics, social characteristics, outcomes and clusters, respectively.

A total of 10 points of view regarding motivations, objectives and context (out of 16) appeared to be related significantly ($P < 0.20$) to clusters. The production system variables were poorly related to the clusters of culling decisions, whereas some psychosocial characteristics were related to them (AGE, SCHOOL, TALK, ISOLATED, INTEGRATED). It was noteworthy that DISTRICT and GROUP were not associated to a given cluster, possibly meaning that the group effect did not interfere in the farmer's culling decisions.

Names were given to each cluster, summarizing a way of thinking and acting with regard to culling.

Cluster 1: the multi-criteria conventionals

The multi-criteria conventionals formed the largest cluster corresponding to 37% of the dairy farmers. Their culling decisions tended to be expressed in a voluntary perspective, in agreement with their objectives for seasonal calving (SEASCALV), and for selection (SELOBJ). These farmers also stressed the effect of the quota context, as shown by the high frequency of QUOTA. Keeping cows as long as possible in the herd is also a main goal for them (KEEP, LONGEV). However, they tended to comply for average frequency with all motivations, factors of context, objectives, compared to other clusters.

Cluster 2: the passive traditionals

The farmers in this cluster showed a low interest in voluntary culling decisions (NODELAY, SELECTION), compared with clusters 1, 3 and 4, possibly as consequences of a low interest in SELOBJ, SEASCALV. However, their tendency to "let nature doing" (LET) could explain that most of them adopted a tolerant AI rule (NOL). 54% of farmers declared urgent cullings, which, together with the low impact of objectives and modifying practices could partly suggest that culling and replacement were often not chosen.

Despite the highest degree of specialization in milk production (CASH), the low cash received (TAX), together with the low interest in milk price (MILKP) may suggest a traditional way of farming. Farming was an individual business for these farmers, since most of them did not invest in social life (INVPRO, INVDIST), were isolated (ISOLATED), and little integrated in their district. Additionally, they were not talkative (TALK).

This way of farming resulted in the lowest culling and replacement rates. This low turn-over of the herd resulted in a high proportion of farmers declaring age as a main culling reason.

Cluster 3: the activists

The farmers in this cluster demonstrated a strong willingness to cull for selection, in agreement with their declarations on objectives (SELOBJ). Avoiding delayed calvings, strengthened by a disinterest in LONGEV and KEEP, is applied through a strict AI rule. A lot of activist farmers complied with objectives related to selection, possibly meaning that they want to manage the herd turn-over. The low percentage of activist farmers who declared EXACT (not shown) suggested that they wanted to keep some 'degrees of freedom' towards replacement. It was noteworthy that they did not declare any urgent cullings.

The fact that only 57% of these farmers were affiliated to the milk recording agency could be because 50% of them were also beef farmers. The lower mean CASH of these farmers strengthened the assumption of an other activity carried out in the corresponding farms. Similarly to the tolerant voluntarists, these farmers tended to be higher educated (SCHOOL) and more integrated in the district (INTEGRATED), may be in relation to their intermediate degree of expression (TALK), than those in other clusters.

More farmers tended to declare more voluntary culling reasons, but less due to infertility, compared to other clusters. This could be related to the percentage associated with NODELAY, meaning that the cullings of some non-pregnant cows at a given date were considered to be voluntary cullings and not cullings for failure to conceive.

<u>**Cluster 4: the tolerant voluntarists**</u>

Similarly to the activists, most of the farmers in this cluster declared voluntary culling decisions, which seemed to be consequences of their declared objectives (SELOBJ, SEASCALV). However, their wish to avoid delayed calving was not followed by a strict AI rule, but a flexible one (FLEX). Their objectives to keep enough cows, as long as possible, in the herd (KEEP, LONGEV), combined with the occurrence of urgent cullings (URGENT) could explain this type of insemination rule. The low percentage associated with EXACT (not shown) could also be understood as a consequence of experiencing urgent cullings (URGENT).

Although a large majority was affiliated to the milk recording agency, the farmers, in agreement with the activists, were not specialized in milk production (CASH), possibly because of additional fodder production (LAND, LANDMAN). This extra activity, which was not related to animals, could partly explain the occurrence of urgent cullings (e.g., due to calving accidents), because of the lower time spent in taking care of cows. A voluntary behaviour towards culling appeared to be associated with a higher level of education (SCHOOL), which was related to a younger age (AGE). Additionally, these young farmers were the most talkative (TALK), the most integrated (INTEGRATED) and received a lot of information from external advisors (OPENED).

<u>**Cluster 5: the silent traditionals**</u>

Compared with the other clusters, this group of farmers had the lowest compliance on all declarations, and ranked fifth on almost all declarations. Parallelly, TALK has also the lowest level, meaning a relative simplicity in arguments. These farmers did not show any interest in the culling decisions, objectives of selection (SELOBJ) and voluntary replacement (VOLREPL) (not shown). By contrast, most of them declared LET, strongly suggesting that the objectives and modifying practices had a low influence on culling practices. These practices seemed to fluctuate with conjunctural adaptations.

Furthermore, these farmers, mostly not affiliated to the milk recording agency, manage a small herd (COW, QUOTA), and received a low cash (TAX). These farmers were the less educated (SCHOOL, AGE). The fact that they were the less integrated (INTEGRATED), showed less openess (OPENED) lightened a lack of investment in the social network (INVPRO, INVDIST).

The disinterest towards the topic could originate from a more general lack of economic motivations (MILKP, CARCASS). Similarly to the passive traditionals, a high level of declaration combining age and infertility as culling reasons could reflect more traditional points of view regarding culling.

Table 4. Percentage of farmers in each cluster who declared the synthetic items relative to culling decisions (n=67).

Culling decisions[1]	Clusters of culling decisions					
	Multi-criteria conventionals (n=25)	Passive traditionals (n=13)	Activists (n=14)	Tolerant voluntarists (n=7)	Silent traditionals (n=8)	Significance (χ^2-df=4)
NODELAY	52	23	64	71	0	****
SELECTION	96	53	78	100	0	****
HEALTH	92	54	71	71	38	**
AI RULES[2]	0-100-0	76-0-24	0-0-100	0-100-0	0-100-0	****
URGENT	0	54	0	100	0	****
CQUOTA	24	31	43	14	13	NS

[1]For definition, see Table 2.
[2]percentages regarding successively the AI rules NOL, FLEX, and AI3.
$^{**}P < 0.10$; $^{****}P < 0.01$; NS: non significant ($P > 0.20$).

Table 5. Percentage of farmers in each cluster who declared points of view relative to motivations, factors of context, objectives (n=67).

	Clusters of culling decisions					
	Multi-criteria conventionals (n=25)	Passive traditionals (n=13)	Activists (n=14)	Tolerant voluntarists (n=7)	Silent traditionals (n=8)	Significance (χ^2-df=4)
Motivations[1]						
MILKP	92	62	93	100	63	***
CARCASS	76	100	93	100	63	***
CALF	4	15	14	0	25	NS
WORK	20	31	21	14	13	NS
Factors of context[1]						
QUOTA	44	11	33	11	0	NS
KEEP	28	23	7	57	13	*
AI	24	31	14	29	63	*
BULL	15	23	38	29	13	NS
Objectives[1]						
SELOBJ	100	77	93	100	63	***
PROTEIN	84	54	85	85	50	***
TYPE	52	38	57	71	13	*
UDDER	28	15	14	57	0	**
YIELD	28	46	21	29	13	NS
SEASCALV	60	15	21	57	25	***
LONGEV	44	23	7	71	13	***
LET	24	38	21	14	38	NS

[1]For definition, see Table 2.
$^{*}P < 0.20$; $^{**}P < 0.10$; $^{***}P < 0.05$.

Table 6. Characteristics of farms in each cluster with regard to production system variables (n=67).

Production system variables[1]	Clusters of culling decisions: Multi-criteria conventionals (n=25)	Passive traditionals (n=13)	Activists (n=14)	Tolerant voluntarists (n=7)	Silent traditionals (n=8)	Significance
BREED[2]	76	77	86	71	75	NS
MILK[2]	76	77	57	86	13	***
LAND, ha[3]	57.8	55.0	59.6	73.7	48	NS
MAN, n[3]	1.5	1.5	1.5	1.4	1.3	NS
COW, n[3]	29	33	32.6	31.3	21.1	*
QUOTA, kg[3]	179700	198300	192700	190900	121600	NS
QUOTACOW[3]	6090	5910	5780	6100	5740	NS
QUOTALAND[3]	4380	4580	4540	4000	3210	NS
COWMAN[3]	21	23.2	23.4	23.3	17	NS
LANDMAN[3]	30.7	30	31.4	44	32	*
CROPS, %[3]	76	82	78	76	83	NS
CORN, %[3]	28	26	33	24	20	*
BEEF[2]	20	23	50	29	50	NS
CASH, %[3]	73	78	64	64	62	NS
TAX[2]	44	62	36	14	75	*

[1]For definition, see Table *1*.
[2]Percentage of dairy farmers who declared the first modality of the variable.
[3]Mean of the variable
$^{*}P < 0.20$; $^{**}P < 0.10$; $^{***}P < 0.05$.

Table 7. Characteristics of farms in each cluster with regard to socio-demographic characteristics and personal social status (n=67).

	Clusters of culling decisions					
	Multi-criteria conventionals (n=25)	Passive traditionals (n=13)	Activists (n=14)	Tolerant voluntarists (n=7)	Silent traditionals (n=8)	Significance
Socio-demographic characteristics[1]						
AGE, yr[2]	42	44	41	36	46	***
SCHOOL[3]	40	62	29	14	63	***
FAMILY[3]	68	77	86	86	62	NS
INVPRO[3]	52	38	50	71	25	NS
INVDIST[3]	52	38	50	71	25	NS
TALK[4]	8-64-28	38-46-16	21-71-8	0-43-57	88-12-0	*
Personal social status (resulting from the social relational network)[1]						
DISTRICT						
district 1[5]	38	24	19	11	8	NS
district 2[5]	44	11	22	6	17	NS
district 3[5]	24	17	25	17	17	NS
GROUP	-	-	-	-	-	NS
ISOLATED[c]	4	38	14	14	0	***
INTEGRATED, %[2]						
in district 1	16	11	14	22	11	***
in district 2	70	80	70	71	27	**
in district 3	33	22	58	36	22	**
OPENED, n[2]						
in district 1	1.2	1.2	1.4	2.8	0.7	NS
in district 2	1.9	4.5	1.75	2	1.7	NS
in district 3	6	2.5	4	4.5	1	NS

[1]For definition, see Table 1.
[2]Mean of the variable
[3]Percentage of dairy farmers who declared the first modality of the variable.
[4]Percentages regarding successively the number of declared points of view (<6; 6 to 10; >10).
[5]Percentage of farmers from the district in the corresponding cluster.
*$P < 0.20$; **$P < 0.10$; ***$P < 0.05$.

Perspectives and limitations

This study, based on farmers' perceptions towards culling of dairy cows, shows that the culling decision is a complex, dynamic and variable process, involving concomitantly environmental factors, such as quotas, intrinsic factors, such as production system characteristics of the farm, and also farmers' goals, conceptions toward farming, and social characteristics and status. At least one variable from each group of information, that is the points of view, the production system characteristics, the socio-demographic characteristics, and the social status of farmers, was significantly associated to each cluster. This suggests that the culling decision process is completely embedded in the whole farming process, strengthening the relevancy of comprehensive studies to better understand culling practices.

Table 8. Characteristics of farms in each cluster with regard to outcomes (n=67).

	Clusters of culling decisions					
	Multicriteria conventionals (n=25)	Passive traditionals (n=13)	Activists (n=14)	Tolerant voluntarists (n=7)	Silent traditionals (n=8)	Significance
CULLR[1]						
Low milk yield[2]	36	15	29	43	0	NS
Age[2]	48	85	64	29	88	***
Other voluntary (protein content, behaviour...)[2]	32	15	64	43	0	***
Infertility[2]	88	92	57	100	100	***
Other involuntary (mastitis, lameness)[2]	48	38	50	57	25	NS
Quotas[2]	12	8	0	29	0	NS
CULLRATE, %[3,5]	32.4	23.5	29.8	33.3	29.6	*
REPLRATE, %[4,5]	32.5	27.9	29.1	32.3	28.5	NS

[1]For definition, see Table 1.
[2]Percentage of dairy farmers who declared this culling reason.
[3]defined as CULLN divided by the declared number of present cows
[4]defined as REPLN divided by the declared number of present cows
[5]Mean of the variable
*$P < 0.20$; **$P < 0.10$; ***$P < 0.05$.

The description of different clusters, based on farmers' declarations, demonstrates the evidence of different ways of thinking and deciding regarding culling. However, the relative impact of each point of view varies between them. Gasson (1988) cited by Fairweather and Keating (1994) reported that goal priorities and the relative ordering of them determine how farmers act. Although the items were not ranked in the present study, declaring or not particular goals through motivations, objectives or related practices can be assumed as partly structuring farmers' conceptions of farming. Among the five groups identified, the activists and tolerant voluntarists tend to represent a strategical attitude toward culling, whereas the passive traditionals appear to act only under the pressure of circumstances, and the silent farmers (the silent traditionals) to 'let the nature doing'.

The low rate of motivations, objectives declared by the passive and silent traditionals together with the evidence of adaptations is similar to findings that culling and replacement stock selection are badly ranked (10 and 7, respectively) in the ten most important critical success factors in 'animal management' cited by Dutch dairy farmers (Huirne et al., 1993).

The social status of farmers (level of integration, isolation, investment in professional organizations) appears to differentiate farmers' attitudes towards culling decisions. The specific and varying responses among farmers may be a consequence of intercommunication, negociating, distancing or rapprochement (van der Ploeg, 1992).

The fact, whether declaring or not some urgent cullings, appears to contribute highly to the differentiation of the activists and the tolerant voluntarists farmers. Furthermore, declaring a lot of cullings by necessity in the context of voluntary objectives seems to result in an AI rule more adaptative than wished. Dijkhuizen et al. (1986) showed that a high rate of involuntary cullings resulted in a significantly lower farm profit. An assumption could then be that, with the same objectives toward culling, the long-term sustainability of the herd managed by tolerant voluntarists would be less than that of activistic farms. However, like all other points of view, this declaration was made in a particular context of interview from a cross-sectional survey, without any possibilities of checking a possible gap between the levels of saying and doing.

More generally, whether or not the points of view reflect the goals and actual practices of farmers with regard to culling is questionable. From this survey, it appears that culling is not a subject of interest per se, when considering the average number of points of view declared by farmers. Special emphasis on this point is given by the silent traditional group. The fact of non arguing should be interpreted with caution, since its exact meaning is unknown (e.g. true non-declaration, negligence, voluntary omission). The low rate of declarations regarding health (see Table 2) may support this hypothesis. Although dairy farmers from The Netherlands and from France rank the disease control as the most important critical success factors in animal management (Huirne et al., 1993; Seegers et al., 1994), it appears, through this study, that herd health problems are not discussed between farmers.

The farmers tend to make culling decisions on their own, as suggested from results of that study. The group effect, regardless of its nature (district, social group) appears to have a low impact on culling decisions. A possible explanation could be that the assessment of different types of technical standards in a LPG does not imply that all members of a given group run their business in exactly the same way, because variants may exist (Darré, 1989). Furthermore, culling decisions were not a daily concern for farmers, contrary to feeding (Darré, 1985), and, then, were not negociated within the group. In addition, the groups were here defined based on the GERDAL approach, which may not be the most appropriate method for that topic. More attention should be paid to the position of culling in farmers' discourse to understand management styles toward culling. As already suggested for health, the process of culling decision interferes with aspects of farmers' personal goals and temperament. Further research in this direction is needed.

The study design may have influenced both the quantity and quality of arguments. Sol et al. (1984) and Crosse and O'Donovan (1989) showed that the cullings mostly occurred in winter, but rarely in summer. The fact that culling is applied through actions (events), mainly done at preferential times within the quota period (from April 1 to March 31 in the following year), and not routine practices, could have influenced the number of declarations (see the silent traditional group) and the nature of the points of view. Because of a low pressure of circumstances (beginning of the quota period), possibly inducing little attention of farmers given to culling, the study period was probably not the most convenient.

The feasability of several non direct interviews carried out through a study in autumn and winter was not deemed realistic, because of farmers' availability. Repeated questioning on that topic may have also induced biased answers. Furthermore, the pre-survey showed a low quantity of materials directly related to culling and replacement. As a consequence, a more structured questionnaire was built in order to obtain as much information as possible.

From this study, there is evidence that the culling decisions differ from one farmer to another, and that they are sociologically structured and regulated. For clearness of analysis, this study considered separately, on the one hand, culling decisions, and on the other hand, variables relative to farmers' management styles and social status, and to production system. However, the interrelation between these different aspects reported in this study suggests that culling practices are parts of farming styles. Fairweather and Keating (1994) argued for including non economic goals in the different approaches to management. Advisory and extension services, as well as researchers, should become increasingly sensitive to this topic and aware that farmers' conceptions towards farming and their information needs are various and manager-specific (Huirne et al., 1993). More generally, the assessment of farming styles, which describe how farmers combine their strategies, goals and related practices, could help in developing methods for decision making aid, that account for heterogeneity in production systems and farming conceptions.

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GENERAL DISCUSSION

GENERAL DISCUSSION

INTRODUCTION

The study described in this thesis focusses on the health related culling decision in dairy cows, with special attention to the role of farmer's attitude in this process. This thesis is composed of four parts. In the first part, the associations between diseases and culling in dairy cows were reviewed and discussed from the literature. In the second part, the impact of disease on longevity was assessed in terms of risk of culling and in terms of reduced length of productive life (chapters 2, 3 and 5). The third part focussed on methodological issues, and proposed a method accounting for within-cow-dependency of lactations to assess diseases as risk factors for culling. The differences between farmers in their culling decision process were specifically studied in the fourth part through the assessment of the associations between farmers' culling decisions and management styles.

Health is considered in this thesis as one of the many factors that may influence culling of dairy cows. Therefore, the influence of health disorders among all determinants of longevity, will be discussed first. The exit from the herd of a cow experiencing a disease results from a farmer's decision, which depends on many parameters. Thus, in a following step, attention will be given to the process of making culling decisions in relation to health, with special emphasis on the role of farmer's attitude in the culling decision process. Limits and values of methods used will also be elaborated. Applications of the present study and perspectives in the field of herd health management will be presented in a final paragraph.

DISEASE AS A DETERMINANT OF LONGEVITY

Culling reasons as declared by farmers can be used to assess the role of health disorders in the culling decisions (chapter 1). A classification into voluntary and involuntary cullings was reported by Stewart et al. (1977). When the culling decision is predominantly beyond the farmer's control, the culling is considered as involuntary. When the culling decision depends on farmer's choice, the culling is regarded as voluntary. In most studies, cullings related to health are classically classified as involuntary. The fact that at least 50% of the cullings were related to health (chapter 1) suggests that the health disorders appear to have a great influence on culling decision-making.

However, Ducrocq (1987) underlined the subjectivity of these definitions. For instance, cullings for reproduction must be viewed in relation to the farmer's objectives regarding calving pattern. Individual factors not related to health and farm and herd circumstances, such as herd size and socio-economic environment, are also declared by farmers as interfering in the culling decisions. Thus, quotas/surplus is currently often declared as a main reason for culling (Guaquière, 1993). Taking into account both the first and the second declared culling reasons could help in better assessing the role of health in the culling decision process (Beaudeau et al., 1992). However, culling reasons may not describe per se the variety of situations that can be found in dairy production systems.

From farmers' interviews, it can be stated that the final decision-making results from a deep analysis of the combined factors in the general context of the farm. Farmers can analyze some events at the actual individual level, that is without any comparison to other animals in the herd. Such a behaviour may occur when a cow is experiencing a calving problem (Renkema and Stelwagen, 1977). Other diseases are mainly analyzed in a dual perspective, both at the individual level and relatively to the herd. Referring to the herd may cover two complementary aspects. The former is related to the position, in term of disease history and/or zootechnical performance, of the corresponding animal compared to that of others. The latter one corresponds to economic farm characteristics and constraints, such as quotas, which may induce indirectly health related culling decision-making.

Allain and Sébillotte (1989) put forward the notion of determining and predisposing factors in the decision process. Farmers' interviews showed that a same health event could be considered by farmers in different ways. As a predisposing factor for culling, the health disorder is regarded as an event which could not induce culling purely by itself. Other additional factors are the key criteria in the culling decision. As determining factor for culling, the health disorder induces the culling per se or strengthens a predisposing problem. However, the predisposing and determining factors may greatly vary between farms. As a confirmation, chapter 6 showed how culling decisions are completely embedded in the whole farming process and vary from one farm to another.

Nevertheless, there is a need to observe how farmers are used on average to account for health events when deciding about culling cows. The investigation of diseases as risk factors for reduced longevity aimed to provide information on the role of health disorders in average. From chapters 2, 3 and 5, farmers appear to consider first potential milk yield, age and reproductive performance to cull their cows, prior to health events. Among the culling decision rules that potentially contributed to the definition of the five groups of farmers identified in chapter 6, those related to health appeared not to differentiate farmers. Comparisons with previous studies must be made with caution, since none investigated simultaneously all variables not related to health that were included in this study (chapter 1). However, similar general trends were noticed. The risk of culling at old age (Cobo-Abreu et al., 1979; Dohoo and Martin, 1984b; Erb et al., 1985), for low milk yield (Dohoo and Martin, 1984b; Erb et al., 1985) and for poor reproductive performance (Erb et al., 1985; Milian-Suazo et al., 1989) was higher than the one due to the most frequent diseases, such as mastitis.

Diseases are known to affect milk yield and reproductive performance (e.g. Thompson et al., 1983; Dohoo and Martin, 1984a; Lucey and Rowlands, 1984; Lee et al., 1989; Bigras-Poulin et al., 1990a; Bartlett et al., 1991). Milk production and reproductive performance also influence the culling decision. One may wonder if the low risk associated with the occurrence of some diseases (e.g. mastitis) results from the high influence on longevity of milk production combined with the impact of diseases on milk production. A part of the impact of diseases may be included in the milk production effect. To limit a possible confusion due to the effect of diseases on cumulative milk production, milk production variables were built in this study from the milk yield at the peak of lactation, with the assumption that this yield was affected to a lesser extent by disease occurrence. Similar overadjustments could be possible when investigating simultaneously reproductive disorders and performances as risk factors for reduced longevity (chapter 5). However, farmers tend to rank first current zootechnical performances in their culling decision-making as compared to health events. A cow with low milk yield potential and/or non-pregnant is more likely to be culled than a high producing cow or a pregnant one (chapters 2 to 5).

Chapters 2, 3 and 5 showed that farmers were used to mainly take into account the occurrence of udder and reproductive disorders in the health related culling process. The high impact of certain udder disorders (teat injuries and non traumatic udder disorders, mastitis excluded) may be due to the fact that they may prevent the cow from being milked easily, inducing possible extra labour. For the other diseases, economic considerations can be put forward. The fact that a cow with mastitis is almost 2 times more likely to be culled than a healthy cow suggests that discarded milk production and lower milk quality inducing penalties (high milk cell counts) are accounted for by farmers in making culling decisions. Similarly, the increased risk of being culled associated to late metritis and abortion could be explained by an impact on days open, resulting in higher calving intervals. Differences in impact between two health disorders may be explained by variations in farmers' attitudes, depending on the nature of the disease. The occurrence of certain types of health disorders, especially accidents and teat injuries, appears to be related to a high risk of being culled. By contrast, farmers can manage other diseases, i.e. decide to treat first, and/or to make a postponed culling decision. In this latter case, the risk of being culled for a cow having one of these diseases seems to be lower than the one in the former case. Such an assumption was validated in chapters 2, 3, and 5, in which the risk of culling associated with mastitis, high milk somatic cell counts and reproductive disorders was found to be lower as compared to teat injuries.

The effects of diseases were investigated depending on parity of occurrence, in order to assess differential farmers' attitudes in relation to the age of cows. The assumption that diseases occurring in parity 1 would affect more heavily the productive life span of cows than the ones occurring later was verified (chapter 5). A possible explanation is that farmers may not consider a disease, occurring for instance in parity 8, as essential as the same one in parity 1, since, from a managerial point of view, the productive life of the corresponding cow is behind her. Similarly, separating diseases depending on their stage of occurrence was intended to assess how farmers react towards occurrence of a disease at different stages of lactation. This approach, consisting of the identification of risk periods, was used by Bendixen and Åstrand (1989) and Oltenacu et al. (1994), in the case of clinical mastitis. The differential impact of a same disease depending on its stage of occurrence within a lactation could be explained because farmers are used to judge the date of its occurrence relative to two key-times, the peak of lactation and the date of services. It is reasonable to assume that the farmers tend to keep cows experiencing a good start in lactation or pregnant cows. That could partly explain why mastitis after 90 days postpartum had no impact on longevity, and by contrast, why late metritis, possibly inducing a high number of days open, affects longevity. However, other criteria may interfere. The lower impact of some diseases occurring in late stage of lactation could be explained by the lower impact of these health disorders on cumulative milk yield or persistency. In addition, the high impact of mastitis during the dry period may reflect the farmers' fear towards the possible consequences of a mastitis at or early after calving.

These results also suggest that farmers judge early events as determinant factors for future longevity. Van Arendonk (1988) referred to future profitability (expected loss if non optimum replacement decisions are made) as a criterion to make optimal culling decisions. Farmers intuitively consider future profit for making decision, since they account for risks and effects of recurrences of diseases and repeatability of zootechnical performance within and between lactations. Thus, they consider preferentially events in parity 1 and/or early stages of lactation to cull the cows. Looking for criteria for early, predictive identification of animals at risk of heavy technical and economic losses due to health disorders appears to be crucial.

HEALTH IN CULLING DECISION-MAKING PROCESS

Length of productive life vs. lactation as basis for making culling decision

Considering different time-frames for assessing the impact of disease was intended to know if health related cullings were decided taking into account events in the current lactation, or if farmers were used to consider the whole disease history of a cow to make culling decision. In that way, several steps were performed, consisting (1) of evaluating the ability of a cow to start a new lactation, based (1a) on events occurring within the current lactation, (1b) on events occurring in the current and the previous lactations, (2) of investigating the possible effects of disease on the whole productive life of the cows. From this study it appears that farmers mainly take into account current health disorders for making decisions, whereas the contribution of health disorders from the previous lactation is poor. For instance, recurrences of a same disorder in two consecutive lactations seem to be of low importance for farmers, since mastitis, locomotor disorder or milk fever in the previous lactation do not affect the effect of a same event in the current one.

Diseases and immediate vs. postponed cullings

Attention was given to the time of culling, with the assumption that the culling decision process was probably not identical depending on its time in the lactation, and that the effects of disease on culling may show variations. This approach aimed to partly assess in which delay farmers react towards different health events. Therefore, distinction was made, whether the culling was made early or later in the lactation. Chapters 2 and 3 prove that the culling decisions are not made in the same way, depending on the nature of the disease concerned.

Theoretically, a farmer facing a health event has three options. He can choose at each disease occurrence between (i) treating and re-deciding later, (ii) immediately culling the corresponding cow, or (iii) doing nothing with the hope that the cow will recover, especially in case of calving events, such as the "downer cow syndrome".

Two categories of health disorders can be considered. The first one gathers the diseases for which a culling decision is made very quickly, and for which the cow leaves the herd in a short while. Teat injuries, non traumatic udder disorders induce early cullings (chapters 2 and 3). These diseases are mainly related to the fact that they prevent milking. If occurring at calving or early in lactation, the corresponding cow is culled immediately. In case of such diseases at the end of a given lactation, the cow is decided to be culled early in the following lactation, possibly to make profit from the calf. The second group gathers other types of diseases, which do not affect milking ability. In these cases, the exit is generally not immediate. Several reasons could explain these results. First, there is a true choice let to farmers to decide to keep or to cull immediately the cows experiencing these health disorders. For mastitis, farmers may choose to treat first in order to let the cow possibly recover. For reproductive disorders, farmers can usually postpone culling, since the reproductive performance (especially days open) is the key criterion for decision-making. This assumption is strengthened by the interaction found between both abortion and late metritis, and reproductive status

(REPRO) (chapter 2). The farmer may wait for several unsuccessful AI before making a culling decision. Secondly, French farmers are used to let the subfertile cows end their lactation before culling, yielding a large time-gap between the decision-making and the actual exit from the herd. A third group, gathering the diseases with a presumed vital prognosis, was expected to be found. Surprisingly, accidents at calving, which could have been associated to immediate exits, were not reported. Only milk fever can be included in such a group in the present study (chapter 2). The absence of other diseases in this group might possibly be due to the fact that death was excluded from analyses (chapters 2 and 3). When the cows recover, farmers focus then on possible consequences in zootechnical performances, as suggested by the significant effect of the interaction between assistance at calving and reproductive status on late culling (chapter 2).

However, large variability between farms may exist, since farmers' culling rules may highly depend on external criteria, especially farmers' objectives. For instance, although high milk somatic cell counts were found to be associated to a late culling in the chapters 2 and 3, some farmers argue that high somatic cell counts are followed by immediate cullings, irrespective of other individual characteristics, in order to avoid penalties due to lower milk quality. Some farmers are also used to milk some cows, as long as their milk yield is above a certain threshold, which may result in calving to culling intervals over a standard lactation duration. Additionally, the practice of fattening cows before culling may delay the date of exit from the herd. On that basis, the definition of a third subpopulation, corresponding to cows culled very late in lactation may appear relevant, when considering distribution of culled dairy cows by days postpartum (chapter 2). Further research in that direction could be fruitful for a better understanding of the culling decision process.

Taking into account associations between diseases to make culling decisions

Several previous studies reported associations between diseases throughout the lactation (Martin et al., 1982; Dohoo and Martin, 1984a; Erb et al., 1985; Bigras-Poulin et al., 1990b; Gröhn et al., 1990) or health profile throughout the whole lifespan of dairy cows (Faye et al., 1994). In addition, Rowlands et al. (1986) showed that cows were susceptible to recurrences of mastitis and locomotor disorders within the lactation, and from a lactation to the following one. No definitive answer to the question, whether or not the farmers are used to account for sequences of diseases to make culling decisions, was provided in this study. With the use of additive models on the log scale to determine the impact of associations between diseases on longevity, the odds ratio attached to a sequence of two diseases was assumed to be the product of the odds ratio attached to each. Therefore, with the use of this method, farmers were "modelled" as implicitely considering each disorder per se in the culling decision, whereas they probably do not manage additively sequences of health disorders. Looking for interactions between diseases may partly answer the methodological issue, but the interpretation of corresponding results is difficult (chapter 3). Therefore, the description and the assessment of methods focussing on how to define sequences of diseases in longitudinal observational studies and how to include them in modelling approaches are required.

Farmers' management styles and health related culling decisions

The identification of five groups of farmers sharing the same culling rules confirms that high variability exists between farmers regarding the way of thinking and deciding about the cullings (chapter 6). However, farmers appear to be primarily distinguished based on their declared culling rules regarding calving patterns, insemination strategies and genetics. In this context, narrow connections exist between culling decisions and farmers' objectives and motivations. The more the farmers declare objectives of selection and seasonal calving as predominant, the more they decide about cullings in relation to these topics (chapter 6).

Health events do not appear as determining factors in the culling decision process at the herd level. Besides the "silent traditional farmers", who apparently showed no interest for culling as a whole, all other farmers appeared to be self-censured on the particular topic of health related cullings. The fact of non arguing must be interpreted with caution, since its exact meaning is unknown. Farmers may consider health problems as a taboo, because of its association with risk and uncertainty, or because they do not like to show their herd problems in public. The fact that farmers must project the future when making health related culling decisions, can indirectly explain their difficulty to clarify health related culling rules.

However, it is noteworthy that the farmers who argue the most about health events and urgent cullings are the ones that are the most talkative, the most integrated in the social life of the district, and have many relationships with external advisors. In addition, health related culling rules are preferentially declared by the most voluntarist farmers towards selection and seasonal calving. The interrelationships between the psychological aspects of culling decisions, especially those related to health, and, on the one hand, farmers' attitudes towards risk and uncertainty, and, on the other hand, their management styles should be explored more completely to better understand the culling decision process.

VALUES AND LIMITS OF METHODS USED

Choice of investigated diseases

In the present study, like in most observational studies, investigated diseases corresponded to a dysfunction diagnosed by farmers and/or veterinarians. A glossary provided to farmers may limit variability between farms, but a full homogeneization of the data recording among farmers and veterinarians was not feasible. The farmer effect induces variations in (1) attitudes towards health problems, that was accounted for in the term describing the farm effect, (2) the nature of the available data. Thus, part of the farmer effect was included in the structure of the dataset.

High milk somatic cell count records could be considered as reflecting subclinical health disorders, according to the statement that a subclinical form represents a functional and/or anatomical abnormality of the body detectable only by laboratory tests or diagnostic aids (Martin et al., 1987). Contrary to clinical diseases, milk somatic cell counts did not constitute direct (that is daily diagnosed by the farmer himself) information available to farmers. This information, received each month from the milk recording agency, might not be read by some farmers. However, somatic cell counts were known to be a major component because of their direct implication in the milk price in case of lower milk quality and were therefore included in the analyses.

Among all diagnoses recorded by farmers, a priori choices were only based on their incidence in this study, to account for modelling constraint. Contrary to previous studies (chapter 1), this procedure generated (1) results concerning all the major health disorders that occur in dairy cows, (2) possibly more accurate estimators of the effect of each disease. A health disorder, if candidate and not included in the models, may become a potential confounder.

Another strategy of classification would have been to account for the severity of the health events, especially regarding mastitis and locomotor disorders. However, the fact that both farmers and veterinarians recorded the events would certainly have induced bias in this respect. Handling them as different whether they were recorded by the farmer or not was not deemed appropriate. Furthermore, no objective criteria were available to assess the severity of diseases. Finally, such classifications, which may have induced very low incidences for several health disorders, would also have resulted in a decrease of power of corresponding analyses.

Measures of longevity

Culling was considered in chapter 2, 3, and 4 as a descriptor of the status of the cow at the end of a given lactation, regardless of its duration. The chance of starting a new lactation, depending on possible occurrences of diseases, was deemed as a relevant approach to assess the associations between health and longevity because it allows to account for the perceptions of farmers who consider calvings as significant thresholds in the productive life of cows. In addition, measuring longevity as a binary dichotomous variable allowed to use logistic regression (Breslow and Day, 1980), providing odds ratios that would be comparable with outputs from previous studies. Furthermore, the availability of existing software led us to choose this approach in a first step.

In a second step, the effect of diseases on length of productive life was assessed using survival analysis. Length of productive life, defined as the number of days between the date of first calving and the date of exit, was preferred to the consideration of the whole lifespan of cows because this latter parameter includes the unproductive period of rearing heifers. No information on this period was available to us in the dataset. Furthermore, Ducrocq (1994) showed that the age at first calving had no impact on longevity of cows. Contrary to standard regression techniques used, in which cows must be classified as culled or not culled, this method allows to use partial information. Besides hazard ratios, which are the parameters most comparable to those resulting from classical regression methods, the other specific outputs from survival analysis techniques allow to better describe the dynamics of the culling process in relation to health history. The variety of situations which can be modelled and illustrated by expected survivor curves (for instance, cows with one health disorder at a given time post-partum, combinations of health disorders, occurrence of a reproductive disorder with an impact on days open...), and the flexibility and the easiness of use made it relevant to perform survival analyses to assess the relationships between diseases and longevity.

Another approach could have been considering diseases as risk factors for specific reasons for culling, as already done by Milian-Suazo et al. (1989). Such a methodological choice could have been possible using the dataset available to us. Assessing diseases as risk factors for specific reasons for culling would have contributed in part to answer the general objective of this study. However, culling reasons are often recognized as subjective (Ducrocq, 1987). A very productive cow bred four or five times unsuccessfully would be considered as involuntarily culled for subfertility. Likewise, a low producing cow may be culled after one or two services and be classified as subfertile although she was not given the same opportunities to conceive. In addition, culling reasons, as stated by farmers, may not always reflect their actual practices toward culling and replacement, such as desired culling and calving patterns which may interfere with their culling decisions. Moreover, Beaudeau et al. (1992) showed that accounting for the culling reasons declared in second might modify the interpretation of the farmers' culling decision process. Some farmers are used to declare only one culling reason, whereas others often cite at least two culling reasons. Thus, some primary voluntary culling reasons (for instance low milk production) are sometimes justified by the declaration of a second culling reason related to health, or related to the socioeconomic environment (surplus due to milk quotas). The absence of both recorded secondary culling reasons in the data and objective criteria to culling reasons led us to analyze culling as a crude event.

Time-frames considered to investigate health related cullings

Because of its relationship with longevity, time was a central methodological issue in this study. It was therefore integrated as component in the definitions of both explanatory and dependent variables, leading to the use of different statistical methods and procedures of analysis. The influence of these methodological choices is discussed hereafter.

The units of analysis chosen, which went from the elementary biological cycle, i.e. the lactation, to the whole productive lifespan of dairy cows, appear by nature to be complementary for the assessment of the impact of diseases on longevity.

Under the assumption that farmers can take into account the whole disease history of the cows to make culling decisions, the impact of health disorders from one lactation on culling in the following lactation was assessed (chapter 3). This procedure resulted in giving the same weight to diseases, in the decision-making, regardless of the interval between occurrence and culling. Such an assumption may not be relevant for most diseases, because, intuitively, the farmers may consider first the current health disorders before accounting for the ones having occurred previously. Furthermore, for some cows only the events from the current lactation are accounted for by the farmer to make a decision, whereas for others this information is not considered as enough. How to model these differences was difficult to assess. A first solution, consisting of selecting the diseases occurring in the previous lactation to be accounted for, was not retained, because it might lead to bias due to an a priori selection. A second solution could have consisted of a three stage procedure. In the first step, a model could have been built with all health disorders from the current lactation significantly related to culling. In the second stage, diseases from the previous could have been selected based on their contribution to culling, after sequential addition to the final model resulting from the first step. In the third stage, a backward procedure, with all events from the current lactation forced into the model, could have resulted in assessing the risk of culling to diseases from the previous lactation.

Definition of diseases themselves did not allow to assess the actual long-term impact of diseases on longevity. Chapter 5 showed a large decrease in median length of productive life for cows with a health event in first lactation, compared to a healthy one. However, most health disorders were defined as having effect within the lactation, based on findings from chapter 3. When looking carefully to survival curves, there was no actual long-term impact of diseases, but a decrease in the fraction still alive, as the expression of the impact of this disease throughout the lactation of occurrence combined with the aging process. A way to assess the true long-term impact of diseases on longevity would have been to define health disorders with an effect duration over one lactation. This was judged unappropriate for two reasons. First, such a procedure would have resulted in considering each new event of a given disease as a recurrence, which sounded unadequate from a managerial point of view. Secondly, it was deemed unlikely that farmers account for the existence of a disease occurring three lactations ago in their current decision-making.

The most appropriate procedure would have been to define health disorders having a duration of effect depending on their nature. For instance, one can assume that farmers do not consider that retained placenta contributes to a possible reduction of longevity throughout a complete lactation. Furthermore, the duration of the impact of a given disease may also depend on its severity and consequently on the time spent by the cow to recover. However, such hypotheses, although relevant in a biological and managerial point of view, were considered very difficult to model.

Farm effect

The two main directions chosen to investigate the relationships between diseases and longevity resulted in two different approaches for assessing the farm effect. To investigate individual risk factors (diseases, age, level of milk yield, reproductive performance...), farm effect was accounted for but not explained, whereas the farm effect was specifically studied in chapter 6. Besides individual factors accounted for by farmers to make culling decisions, farm factors may influence the risk of culling (chapter 6). Instead of taking into account the farm effect as whole in chapters 2, 3 and 5, splitting it in several factors (including a random unexplained effect) that possibly influence the risk of culling, is valid from a statistical viewpoint. Such a procedure was used by Frankena et al. (1993), Puyalto (1993) and Ducrocq (1994). Puyalto (1993) showed that either accounting for the herd effect or introducing several explanatory herd factors in the models did not change the computed solutions for individual factors in her dataset.

The dataset available to us did not provide any relevant herd criteria to be included in the models. Nevertheless, some herd criteria, such as monthly culling rate, variation in herd size throughout the quota campaign, percentage of milk yield produced relatively to the quota reference, may influence the individual risk for culling. The calculation of some of these factors, although possible from individual data, would have resulted in high losses of observations to be included in the models, because (1) in the available dataset, the herd sizes were stabilized around February 1987, allowing the calculation of herd factors only from this date, and (2) some factors, such as culling rates, could have been only attributed to the observations (i.e. lactations) that were not accounted for in their assessment. If available, larger datasets including both individual and farm data could allow to assess the influence of farm circumstances, which appear to be interrelated to individual culling decisions (chapter 6). A drawback of such a method could be the difficulty of interpreting outcomes, in case of interactions between diseases and farm factors included in models. However, this procedure would allow to rank the farm factors hypothetically influencing longevity.

Accounting for two levels of nested effects

Cows from a same herd, despite variations in individual characteristics, are presumed more similar than those from two different herds, because they are managed in the same environment. In other words, there is a herd effect. Furthermore, a cow with a given health disorder in one lactation is more likely to experience it or another disorder in the following lactation (Rowlands et al., 1986), suggesting that lactations are not independent. In other words, there is a cow effect. Accounting for one group effect in multiple logistic regression is now documented (Mauritsen, 1984; Curtis et al., 1993; McDermott et al., 1994). Logistic binomial regression is used in veterinary epidemiological studies to account for the herd effect (Curtis et al., 1993; Frankena et al., 1993; chapters 2 and 3). As in numerous epidemiological studies, a new problem arises when the unit of analysis is the lactation (chapter 2) or the pair of lactations (chapter 3), because the observations are structurally not independent.

The method proposed in chapter 4 accounting for non-independence of lactations must be viewed as a first contribution to analyze clustered binary data with numerous small size clusters, together with a mean to validate outputs of previous analyses. The overall agreement in results when accounting or not for dependency of observations produces evidence to the reliability of results from chapters 2 and 3. The obvious drawback of the method in chapter 4 is the relatively huge computing time needed. Two options were possible to account for the cow effect. The method proposed in chapter 4 corresponded to get rid of this effect by repeated random selections. The other one would have consisted of adjusting for this effect. Rosner (1989) generalized a beta-binomial model when data are clustered at more than one level, but no software was available to us to apply this method. Further research in that direction would be greatly appreciated for defining methods to be used in epidemiological studies of large animal populations, in which such statistical constraints often occur.

APPLICATIONS AND PROSPECTIVES IN HERD HEALTH MANAGEMENT

The different chapters of this thesis show how farmers on average account for health disorders to decide about culling cows or not. Despite variability between farms and farmers, the average impact of disease on longevity suggests that some diseases may have a high economic impact through anticipated culling. Therefore, controlling diseases may contribute indirectly in the lowering of the production costs through increased longevity of dairy cows.

Technical and economic consequences of diseases include mortality and abortions, costs of treatments, regulatory cullings, discarded products and slaughter refusals, penalties on selling prices, emergency cullings, costs of preventive interventions, reduction in milk and meat productivity, increasing culling rate, decrease in genetic improvement and additional labour costs (Renkema, 1980; Dijkhuizen, 1983; Seegers et al., 1994). For measuring the economic impact of disease, the evaluation of the related mortality and culling, and the effect on production is a first step. The conversion of these effects into economic and financial terms is the second one.

This study provides contributing results for measuring the economic impact of disease at the individual level. Extensive information on the risk of reduced longevity was given. Furthermore, outputs from survival analysis, which provide time-specific probabilities of culling after occurrence of a given disease or combination of diseases, compared with those of a cow without any disease could be used for the calculation of the marginal cost due to each extra day of life lost.

To improve farm management and help the farmers in making either short-term decisions related to health (especially culling decisions and treatment...) or long-term decision (selection...), the early and predictive identification of animals at risk, in terms of future economic losses, is also worthwhile. Results from this study demonstrate the relevance of investigating on early predictors of animals at risk, since early diseases (in early stage of lactation, and/or in parity 1) appeared to induce the highest negative impact on longevity (chapter 5). The early identification of animals with a higher risk of reduced longevity would be a powerful tool for health management. The assessment of survival curves of theoretical cows after assuming a priori values of covariates (chapter 5) could be extended to real life cows.

The quantification of the technical and economic impact of disease, especially through anticipated cullings, is also worthwhile for determining priorities between target diseases for intervention in health schemes (Seegers et al., 1994). However, the worth of interventions to control diseases, particularly those which heavily affect longevity, must be considered in a specific farm. Indeed, the consequences of these health disorders affect only the considered farm. The level of risk factors present varies highly between farms and farmers' perception, and attitude towards risk regarding health disorders may also greatly differ (Pardon and Denis, 1982). To determine target diseases for control in health programs, the true impact on longevity of a health disorder has to be estimated in the particular context of the farm.

To account for farmers and farm specificities, the collection of farm characteristics, that may influence health related culling decisions is needed (Huirne et al., 1993). Farmers' interviews allow to list interrelated topics, which could allow a better assessment of the actual impact of disease on longevity. These are

(1) *farmers' objectives* towards culling and replacement, and related topics, such as genetics (selection, genetic improvement...), reproduction, calving patterns, quotas management. Farmers' strategies may differ in equivalent situations, because of variations in motivations (Enevoldsen et al., 1992, chapter 6). It appears that only some farmers clearly identify culling rules regarding health, in relation to their motivations. For instance, the willingness of avoiding penalties due to high milk cell counts lead some farmers to cull the animals immediately. Therefore, a thorough assessment of the farmers' motivations seems to be essential.

(2) *factors of freedom* let to the farmers regarding culling decision at a given time. An identical culling decision rule concerning a cow experiencing a given disease cannot be used, whether this decision has to be made at either the beginning of the quota campaign or the end, because the actual degree of freedom let to the concerned farmer with regard to culling will generally vary throughout the campaign. These factors of freedom result from combinations of farmers' objectives and present values of key criteria. Among a lot of potential components, the milk yield to be produced to reach the quota reference, the number of involuntary cullings already done relative to the initially planned number and the avaibility of heifers still to be calved could be considered by some farmers as factors of freedom. For most farmers, there is a quasi-permanent adaptation all along the process. A large field of study appears to be unexplored.

Special efforts should be made by the researchers on how to choose criteria, describing the factors of freedom to be accounted for, and how to define them (e.g. as time-dependent variables) to be used in modelling approaches.

(3) *herd structure and characteristics*. Some farmers declare that their culling decisions for health were often associated to the age of the cow, and to her milk yield in deviation of the herd structure or to the average milk yield per cow present. For old and/or low producing cows, a health event is often considered as an additional unfavourable factor. By contrast, the farmer will be tempted to treat the animal first, if well ranked in the herd.

(4) *disease incidence*. It is reasonable to consider that the farmer will make a culling decision for a given disease after having evaluated its incidence at the herd level. A high incidence, together with the existence of a herd health program could increase the individual risk.

(5) *economic environment and constraints*. For most farmers quotas are considered as a main constraint. Quotas are often viewed as an additional determining factor in making culling decision for health events. Furthermore, the willingness not to exceed quota reference may lead some farmers to speed up exits that were planned but initially postponed. In addition, other factors such as beef market variations may influence the dates chosen for exit.

(6) *sociological environment*. The role of co-workers within the farm (wife, employees...) together with that of advisors should be studied, since some farmers declare that their wife, who often attends milking, and the milk recording agency advisor, may influence the culling decision process, e.g. in case of mastitis or high milk somatic cell counts.

The farmer is the central player in the culling decision. Emphasis must be put on why and how farmers make culling decisions regarding health. Health is often associated with uncertainty. Whether a diseased animal should be kept and treated or immediately culled is a daily problem to be solved by farmers. The expected outcome (e.g. recovering) after a treatment is usually not known with certainty. The culling decision is then made accounting for risk and uncertainty, and therefore the farmer is supposed to project the future. Previous management guidelines for the individual replacement of the dairy cow did not account for risk and uncertainty (van Arendonk, 1988; Stott and Kennedy, 1993). Two approaches could be carried out to account for the specificity of the farmer in the culling decision process.

(1) The farmers' preferences accounting for their attitude towards risk, using the utility concept (von Neumann and Morgenstern, 1947) could be a first field of interest. Most studies performed in the field of agriculture showed that farmers were generally risk-averse (Hardaker, 1982). The application of this approach to the field of health and longevity could be added to the assessment of different farming styles towards culling.

(2) A second approach could consist of applying the concept developed by Sébillotte and Soler (1988) for the understanding of the farmers' behaviour. This approach could help farmers in formulating culling rules, then analyzing them together with the consequences of others, finally solving the problem (to cull or to keep). Through in-depth interviews the culling decision process of farmers could be modelled. Work could focus (i) on the importance given by a farmer to culling and replacement practices in the farm process, (ii) on his different types of culling and replacement rules, putting special emphasis on the relationships between the purpose and the time of the culling decision relative to the end of the quota campaign, (iii) on the different factors involved in the decision (identification of the cow potentially candidate for culling, factors which lead to decisions, attitude towards uncertainty, socio-economic environment). The farmers' answers could be helpful in assessing and scaling variables relative to their degrees of freedom throughout the quota campaign. This approach, which also includes the collection of data relative to the production system, the herd and the constraints identified by the farmer, should not be restricted to the relations between health and longevity, but should rather be performed in the whole context of the dairy farm.

Part or all of these factors must be viewed as modulators of the information provided in this study.

Based on the data collected, different farming styles (Bennett, 1980; van der Ploeg, 1990) could be assessed, in which health related cullings would be a domain of implementation. In a following stage, diseases as risk factors for reduced longevity could be assessed within a given farming style. This approach could be a first step towards support for culling decision-making, including both rational criteria and farmers preferences (Ngategize et al., 1986).

The conversion of the effect of disease in economic terms, especially through anticipated cullings, should also account for these factors. Simulation and decision support models (Dijkhuizen et al., 1986; Marsh et al., 1987; Sorensen et al., 1992; Jalvingh at al., 1993) are now recognized as relevant tools to assess the economic impact of diseases. In the future, such technical means must be able to account for the variable and dynamic factors involved in the management decision process (flexibility of decisions throughout the quota campaign, psychosocial factors, farmers' attitudes towards risk and uncertainty...) to support health-related, operational on-farm decisions.

MAIN CONCLUSIONS FROM THE STUDY

- Logistic regression and survival analysis with time-dependent covariates appear to be complementary ways for investigating the relationships between diseases and longevity in dairy cows. The overall agreement in results from logistic regression when accounting or not for dependency of observations stresses the fact that ignoring the within-cow-dependency of lactations do not lead to large bias in computed solutions in the present study.
- Farmers mainly take into account the occurrence of udder and reproductive disorders in the health related culling process of dairy cows.
- Cows are culled after firstly taking into account events in the current lactation, rather than based on the consideration of their whole disease history, suggesting that farmers account preferentially for current events for making culling decisions.
- Culling decision-making process is dependent on the nature of health disorders. Farmers tend to decide to cull cows with parturient events and/or udder disorders possibly affecting milking ability in a short while after calving, whereas cows with mastitis and reproductive disorders leave the herd later within lactation.
- Culling decision-making process is also dependent on the moment of disease occurrence. Farmers consider preferentially health events occurring in first lactation and/or early stages of lactation to cull the cows. Therefore, there is a need for investigation of criteria for early and predictive identification of animals at risk of heavy technical and economic losses due to health disorders.
- The impact of diseases on longevity is low, compared to those of low milk yield potential and poor reproductive performance.
- Culling decision-making process is sociologically structured and regulated, and

differs from one farmer to another. Advisory and extension services, as well as researchers, should become increasingly sensitive to this topic, when providing farmers with rules or tools for culling decision-making aid.

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SUMMARY

SUMMARY

Since the establishment of the milk production quotas in the European Union, the reduction of production costs has been recognized as a way to maintain or increase farm profit. Variation in replacement costs in French Holstein herds suggests that improvements are possible. An increased longevity of dairy cows lowers the replacement costs per produced litre of milk, and therefore contributes to a higher farm profit.

In that context, based on dairy farmers' declarations, more than one half of cullings are associated with the occurrence of health disorders. Therefore, the quantitative assessment of the effect of diseases on longevity appears to be relevant. However, also farmers' attitudes, especially their objectives and motivations towards farming, may influence the way they account for health in making culling decisions.

The main aim of this study was to assess the relationships between the main health disorders occurring in dairy cows and their longevity. Subsequently, the study focussed on the assessment of the influence of farmers' attitudes on culling decisions.

With respect to effect of disease on longevity, a general outline of the associations between diseases and culling in dairy cows was given in chapter 1. Studies available in the literature were described depending on their designs and results. Large variations between studies, especially with respect to study populations and statistical methods, were observed. Discrepancies were reported for most health disorders, except mastitis and dystocia, for which an increased risk of culling was found in all studies.

Most studies took into account some individual characteristics of dairy cows (age, milk production level, reproductive performance) as possible risk factors for culling. However, the same individual factors are not accounted for in the same way by all farmers. This induces a farm effect on the individual risk for culling. Adjustment for the farm effect on the individual risk for culling was not or poorly applied in most publications. In addition, most studies investigating associations between diseases and culling were performed without considering the moment of culling during lactation, whereas the health related culling decision process is probably not the same whether the cow is culled early or later within the lactation. Based on these conclusions, two approaches were considered to investigate the associations between health disorders and longevity in dairy cows. The study population used consisted of 47 commercial Holstein dairy herds from western France, comprising 4123 dairy cows.

In the first approach (chapters 2 and 3), the relationships between diseases and culling were investigated. Distinction was made whether the cows were culled early (within 45 days postpartum) or later within the lactation. In chapter 2, analyses were done taking into account events from the current lactation. In chapter 3, the unit of analysis was extended to two consecutive lactations, as a way to approximate the whole disease history as risk factor for culling. Logistic regression was used with early or late culling (yes/no) as binary outcome variable. 14 main health disorders with clinical signs (early abortion in lactation, periparturient accident, calving provided with assistance, milk fever, ketosis, mastitis, teat injury, non traumatic udder disorder (nodes, cracks), retained placenta, metritis, cystic ovaries, digestive, locomotor, respiratory disorders) and one subclinical syndrome (high milk cell count) were studied. Adjustments were made for year, month of calving, parity, breeding value for milk, best of the two first milk records and calving to last insemination interval. The possible effect of interactions among variables was also studied. The herd effect was accounted for using a random effect model (binomial logistic regression).

The second approach, described in chapter 5, consisted in using survival analysis to explain the length of productive life (LPL) of cows, defined as the number of days between the date of first calving and the date of exit from the herd. The effect of 16 health disorders (the 15 described above, plus late abortion inducing a new calving) on the length of productive life was studied, using a proportional hazard model (Cox regression). The model included adjustments for effects of herd-year-season (considered as random), month of calving, stage of lactation, lactation number, calving to last insemination interval, level of milk production, fat and protein content of milk. All explanatory variables possibly influencing the risk of being culled were defined as time-dependent.

Attention was focussed on the fact that lactations were not independent within cows, and that cows were not independent within herds for the assessment of individual risk factors for culling. In order to respect the assumption of independency between observations in logistic regression, a method, based on repeated random selection of one pair of two consecutive lactations per cow, was proposed in chapter 4.

10 datasets were created based on repeated random selections of one pair of lactations per cow. These datasets were analysed using logistic regression analyses. A

disease was considered as significantly associated with culling if present in at least 4 final models. Outputs were compared with outputs from logistic regression analyses performed with all the available pairs of lactations, i.e. violating the assumption of independency between observations.

There was an overall agreement in results when accounting or not for dependency of observations, showing that the violation of assumptions did not result in serious bias in the present study.

The results in chapters 2 to 5 showed how farmers are used, on average, to account for diseases when deciding about culling cows. Udder and reproductive disorders were the main diseases influencing the longevity of dairy cows. Mastitis in the early stage of lactation (within 90 days) increased the risk for a cow of being lately culled in the current lactation, but its long-term effect on longevity was low (decrease in median length of productive life of 13 days if it occurred in first lactation). The recurrence within lactation or the occurrence of a mastitis in the previous lactation had no additional impact on LPL. Mastitis during the dry period strongly affected the LPL (decrease in median length of productive life of 443 days if it occurred in parity 2). Teat injuries and non traumatic udder disorders were associated with an increased risk of being early culled in the current and in the following lactations (odds ratios ranging from 3.6 to 6.0). Teat injuries had a significant impact on longevity, especially when they occurred in first lactation, inducing a decrease in median length of productive life over one standard lactation duration. Abortions and late metritis (after 42 days postpartum) were dominant with respect to the risk of being lately culled in the current lactation (odds ratios ranging from 2.3 to 6.2). They significantly reduced LPL, especially when they occurred in first lactation (decrease in median LPL about 180 days).

However, the effect of diseases on longevity appeared to be low, when compared to the effect of milk yield and reproductive performance. The probability of being culled strongly increased in cows with low milk yield (in the 20% bottom of the herd), and/or in cows with a calving to last insemination interval over 150 days. Moreover, cows with lower breeding value for milk were high risk groups for culling.

Chapters 2 to 5 concentrated on the cow level to assess the average risk for culling. In these chapters, the farm effect was statistically accounted for, but not specifically studied. In order to identify the role of farmers (among all determinants at the farm level) on the individual culling decision, a survey was carried out on 67 dairy farms from three administrative districts of western France (chapter 6).

The dairy farmers were interviewed in a semi-direct way to collect (1) their points of view regarding culling and related topics (objectives of selection, reproduction, quotas and health management), (2) their relationships with other farmers and external advisors, (3) socio-demographic characteristics, (4) characteristics of the production system. A social status was defined by indexes of the nature and the frequency of relationships each farmer had with other professionals. The farmers' management styles were defined as specific combinations of objectives and motivations towards farming. Cluster analysis was used to identify groups of farmers that were homogeneous regarding criteria for culling decisions. The relationships between the clusters of culling decisions and farmers' management styles (as defined above), production systems and sociological variables were assessed.

Five groups of dairy farmers were differentiated by their criteria of culling decisions, namely the "multi-criteria conventionals", the "passive traditionals", the "activists", the "tolerant voluntarists", and the "silent traditionals". Farmers' management styles and social status showed variations between these groups, which evidenced that culling decisions were partly sociologically mediated and influenced by farmers' objectives and motivations towards farming.

The chapters 2 to 6 showed how farmers, on average, account for health disorders to decide about culling cows. The average effect of disease on longevity suggests that some health disorders may have a high economic impact through not planned culling. In the discussion chapter, attention was focussed on the contribution of this study for measuring the economic impact of disease at the individual level. Emphasis was given to the relevancy of the early predictive identification of animals at risk, in terms of future economic losses. Furthermore, it was stressed that, the technical and economic consequences of these health disorders must be evaluated within a specific farm for assessing the value of intervention measures to control diseases, using herd health control programmes. A list of parameters accounting for farm and farmer's specificities was proposed, as contributory factors for a better understanding of the true importance of diseases in the culling decision process, in specific farm conditions. Finally, it was emphasized that economic simulation models in support to farmers' culling decision process should take into consideration the sociological component in the decision process.

RESUME

RESUME

Depuis l'instauration des quotas laitiers dans l'Union Européenne, la réduction des coûts de production est considérée comme un moyen de maintenir ou accroître le revenu des exploitations. Dans les troupeaux Prim'Holstein français, l'existence de fortes variations du coût du renouvellement suggère que des améliorations sont possibles dans ce domaine. L'augmentation de la durée de vie productive des vaches laitières est associée à une diminution du coût du renouvellement rapporté au litre de lait produit, et contribue donc à l'augmentation du revenu de l'exploitation.

Les éleveurs de vaches laitières déclarent réformer plus de la moitié de leurs animaux en relation avec la survenue de troubles de santé. Il apparaît donc pertinent dans ce contexte de quantifier l'effet des troubles de santé sur la longévité des vaches laitières. Toutefois, des variations entre élevages existent. L'attitude de l'éleveur, en particulier ses objectifs et motivations en matière de conduite d'élevage, peut influencer la façon dont la santé est prise en compte dans les décisions de réforme.

Le principal objectif de cette étude est de quantifier les relations entre la survenue de troubles de santé et la longévité des vaches laitières. De plus, l'influence de l'attitude de l'éleveur sur les décisions de réforme est évaluée.

L'impact des troubles de santé sur la longévité des vaches laitières est tout d'abord étudié. Les relations entre les troubles de santé et la réforme des vaches font l'objet de la revue de littérature présentée au chapitre 1. Les protocoles mis en oeuvre et les résultats des travaux antérieurs sont décrits. De nombreuses différences entre études, qui concernent en particulier les populations d'étude et les méthodes statistiques employées, sont observées. Des résultats contradictoires sont rapportés, sauf pour certaines affections (mammites et dystocie), qui augmentent la probabilité de réforme.

La plupart des études antérieures prend en compte des caractéristiques individuelles des vaches laitières autres que la santé (âge, niveau de production laitière, résultats de fertilité) comme facteurs de risque de réforme potentiels. Toutefois, les mêmes facteurs individuels ne sont pas pris en considération de la même façon par l'ensemble des éleveurs. Il existe un effet élevage sur le risque individuel de réforme. Cet effet élevage est rarement étudié dans les travaux antérieurs. De plus, les analyses sont effectuées dans la plupart des cas sans tenir compte du moment de la réforme dans la

lactation, alors que le processus de décision de réforme des éleveurs n'est probablement pas identique selon que les vaches concernées sont réformées précocément ou plus tardivement en lactation. Sur la base de ces conclusions, les associations entre troubles de santé et longevité ont été étudiées selon deux approches, en utilisant des données issues d'une enquête longitudinale prospective conduite dans 47 troupeaux Holstein de l'ouest de la France.

La première approche (chapitres 2 et 3) a consisté en l'étude des relations entre troubles de santé et réforme des vaches laitières, en séparant réformes dites précoces (survenant dans les 45 premiers jours de la lactation) et dites tardives (survenant après 45 jours de lactation). Dans le chapitre 2, l'unité d'étude est la lactation, tandis qu'elle est étendue à deux lactations consécutives dans le chapitre 3, afin d'évaluer partiellement l'impact des antécédents sanitaires des vaches sur le risque de réforme. Des analyses par régression logistique ont été réalisées, avec pour variable binaire à expliquer, la réforme dite précoce ou tardive (oui/non). 14 troubles cliniques (avortement survenant précocément en lactation, accident du peri-vêlage, assistance au vêlage, fièvre vitulaire, cétose, mammite, blessure du trayon, affection non traumatique de la mamelle (nodules, crevasses), rétention placentaire, métrite, ovaires kystiques, troubles digestif, respiratoire, locomoteur) et un trouble subclinique (taux cellulaires élevés dans le lait) ont été étudiés. Chaque analyse a été ajustée sur l'année et le mois de vêlage, la parité, l'index quantité de lait, la production laitière au meilleur des deux premiers contrôles et l'intervalle vêlage-dernière insémination. Les interactions ont également été étudiées. Des modèles à effet aléatoire (régression logistique binomiale) ont été utilisés pour prendre en compte l'effet troupeau.

La seconde approche, décrite dans le chapitre 5, a consisté en l'utilisation des techniques d'analyse de survie pour expliquer la durée de vie productive de la vache laitière, définie comme étant le nombre de jours entre la date de premier vêlage et la date de sortie du troupeau. L'effet sur la durée de vie productive des vaches de 16 troubles de santé (les 15 décrits précédemment, ainsi que l'avortement tardif induisant une nouvelle lactation) a été analysé en utilisant un modèle des risques proportionnels (régression de Cox). Le modèle utilisé incluait comme facteurs d'ajustement les effets année-troupeau-saison (en tant qu'effet aléatoire), stade de lactation, numéro de lactation, mois de vêlage, niveau de production laitière, taux butyreux, taux protéique, classe d'intervalle vêlage-dernière insémination. Toutes les variables explicatives ont été définies comme dépendant du temps.

Le fait que les lactations n'étaient pas indépendantes intra-vache, et que les vaches n'étaient pas indépendantes intra-troupeau a fait l'objet d'une attention particulière. Afin de respecter l'hypothèse d'indépendance entre observations pour la régression logistique, une méthode basée sur la sélection aléatoire répétée d'une paire de lactations consécutives par vache, a été proposée dans le chapitre 4.

10 jeux de données issus de tirages aléatoires répétés d'une paire de 2 lactations consécutives par vache ont été créés. Ces jeux de données ont été analysés en utilisant la méthode de régression logistique. Un trouble de santé a été considéré comme significativement lié à la réforme s'il était présent dans au moins 4 modèles finaux. Les résultats ont été comparés à ceux issus d'analyses prenant en compte toutes les paires de 2 lactations consécutives existant dans le jeu de données initial, induisant de ce fait une violation de l'hypothèse d'indépendance entre observations.

La similitude des résultats issus des deux niveaux d'analyses a montré que violer l'hypothèse d'indépendance entre observations n'induisait pas de biais importants dans la présente étude.

Les résultats des chapitres 2 à 5 correpondent à la façon dont les éleveurs, en moyenne, prennent en compte les troubles de santé dans leurs décisions de réforme. Les troubles de la mamelle et de la reproduction sont les troubles majeurs vis à vis de la longévité des vaches laitières. Les mammites de début de lactation (survenant dans les 90 premiers jours de lactation) augmentent le risque de réforme dite tardive dans la lactation en cours, mais leur effet moyen à long terme est faible (diminution de la durée de vie productive médiane de 13 jours, quand elle survient en première lactation). La survenue d'une mammite dans la lactation précédente ou une récurrence dans la lactation en cours n'a pas d'influence sur le risque de réforme pour mammite. Les mammites en période de tarissement ont un fort impact sur la durée de vie productive (diminution de la durée de vie productive médiane de 443 jours, quand elle surviennent entre la deuxième et la troisième lactations). Les blessures du trayon et les affections non traumatiques de la mamelle sont associées à un risque accru de réforme dite précoce dans la lactation en cours et dans la lactation suivante (odds ratios de 3,6 à 6,0). De plus, une blessure du trayon induit une diminution de la durée de vie productive médiane de plus d'une lactation, quand elle survient en première lactation. Les avortements ainsi que les métrites survenant après 42 jours de lactation sont les troubles de santé majeurs vis-à-vis du risque de réforme dite tardive (odds ratios de 2,3 à 6,2). Ces troubles entraînent une diminution significative de la durée de vie productive des vaches, surtout quand ils surviennent en première lactation (diminution de la durée de vie productive médiane d'environ 180 jours).

Ces effets sont faibles en comparaison de ceux liés à un faible niveau de production laitière potentielle et/ou à un intervalle vêlage-dernière insémination élevé. Les vaches avec un faible niveau de production laitière potentielle (situant l'animal dans les 20% inférieurs du troupeau), et/ou avec un intervalle vêlage-dernière insémination supérieur à 150 jours ont un risque de réforme accru (odds ratios supérieurs à 2). De plus, les vaches à index quantité de lait négatif constituent un groupe à risque vis-à-vis de la réforme.

Les chapitres 2 à 5 ont pour objectif l'étude du risque individuel de réforme. Dans ces chapitres, l'effet élevage est pris en compte d'un point de vue statistique, mais non étudié spécifiquement. Afin d'étudier le rôle de l'éleveur sur la décision de réforme individuelle, une enquête a été menée dans 67 élevages bovins laitiers situés dans trois communes de l'ouest de la France (chapitre 6).

Un questionnaire semi-directif a été administré à l'ensemble des éleveurs laitiers. Ont été collectés (1) leurs points de vue concernant la réforme et certaines pratiques qui lui sont liée (objectifs de sélection, conduite de la reproduction, gestion des quotas et de la santé du troupeau), (2) leurs relations avec les autres éleveurs et les conseillers et techniciens d'élevage, (3) leurs caractéristiques socio-démographiques, (4) certaines caractéristiques de système de production. La nature et le nombre de relations que l'éleveur entretient avec son entourage professionnel a permis de définir un statut social pour chaque éleveur. Chaque style d'éleveurs a été défini comme une combinaison des objectifs et motivations déclarés par ceux-ci. Une méthode de classification automatique a été utilisée pour identifier des groupes d'éleveurs homogènes au regard des règles de décision de réforme qu'ils déclaraient. Les relations entre, d'une part, ces groupes, et, d'autre part, les styles d'éleveurs (définis précédemment), les caractéristiques du système de production et les variables sociologiques ont été étudiées.

Cinq groupes d'éleveurs laitiers - "les conventionnels multi-critères, les traditionnels passifs, les activistes, les volontaristes tolérants, les traditionnels silencieux" - ont été identifiés. Il existent entre ces groupes des différences concernant les styles et statuts sociaux des éleveurs. Les décisions de réforme apparaissent donc liées aux objectifs et motivations des éleveurs en matière de conduite de troupeau.

Les chapitres 2 à 6 montrent comment les éleveurs, en moyenne, tiennent compte

de la santé de leurs animaux pour décider ou non de les réformer. S'il existe de fortes variations entre élevages et éleveurs, l'effet moyen des troubles de santé sur la longévité des vaches laitières suggère que certaines maladies peuvent avoir un impact économique important, notamment en raison du risque de réforme anticipée qu'elles induisent. Dans la discussion générale, l'utilisation des résultats de cette étude pour la mesure de l'impact économique des troubles de santé à l'échelle individuelle est décrite. La pertinence de l'identification en début de carrière d'animaux à risque en terme de pertes économiques futures, est soulignée. Toutefois, pour évaluer l'intérêt de mesures de contrôle des troubles de santé dans un élevage, l'impact technique et économique de ces troubles de santé doit être quantifié dans les conditions propres à celui-ci. Afin de contribuer à une meilleure compréhension de l'importance réelle des troubles de santé dans les processus de décision de réforme, une liste de paramètres décrivant les spécificités de l'élevage et de l'éleveur à prendre en compte est proposée. L'accent est mis sur l'intérêt qu'il y aurait à intégrer la composante sociologique des processus décisionnels dans les modèles de simulation économique pour l'aide à la décision de réforme.

SAMENVATTING

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Sinds het invoeren van de melk quotering in de Europese Gemeenschap wordt er meer aandacht besteed aan het verlagen van de produktiekosten teneinde op die manier het rendement op melkveebedrijven te verhogen. De variatie die bestaat tussen Frans-Holstein melkveebedrijven met betrekking tot vervangingskosten van de dieren geeft aan dat dit een potentiële factor is om het rendement op een aantal bedrijven te verhogen. Een langere levensduur van de koeien zal de vervangingskosten per liter melk verlagen en daardoor leiden tot een hoger rendement.

Uit praktijkonderzoek is gebleken dat de reden van afvoer van dieren in meer dan de helft van de gevallen gerelateerd is aan gezondheidsstoornissen. Om die reden is een kwantificering van de effecten van het optreden van ziekten op de levensduur relevant. Ook de managementstijl die de veehouder voert kan een rol spelen bij de mate waarin gezondheid wordt betrokken bij de beslissing tot afvoer van dieren.

Het hoofddoel van dit onderzoek bestond uit het kwantificeren van de relaties tussen de belangrijkste gezondheidsstoornissen van melkvee enerzijds en de levensduur anderzijds. Daarna werd de rol van de gevoerde managementstijl bij de afvoerbeslissingen bestudeerd.

In hoofdstuk 1 wordt een algemeen overzicht gegeven van de relaties tussen optreden van ziekte en afvoer van melkkoeien. Gepubliceerde onderzoeken worden, op basis van onderzoeksopzet en resultaten, op een rij gezet. Er blijkt een grote variatie te bestaan tussen deze onderzoeken, vooral aangaande de onderzoekspopulatie en de gebruikte statistische methoden. Tegenstrijdigheden worden gevonden voor de meeste gezondheidsstoornissen, behalve voor mastitis en dystocia, die beide het risico op afvoer verhogen in alle onderzoeken.

In de meeste onderzoeken wordt rekening gehouden met individuele dierkenmerken (leeftijd, melkproduktie, reproduktie) als mogelijke risicofactoren voor afvoer. Deze dierfactoren worden niet door alle veehouders gelijk geïnterpreteerd, hetgeen een bedrijfseffect induceert. Het corrigeren voor bedrijfseffecten op het individuele risico op afvoer wordt in de publikaties niet of slecht toegepast. In de meeste onderzoeken wordt ook geen rekening gehouden met het moment in de lactatie waarop dieren worden afgevoerd, terwijl de rol van gezondheid bij de afvoerbeslissing waarschijnlijk niet dezelfde is als het dier vroeg dan wel laat in de lactatie wordt afgevoerd. Op basis van het literatuuronderzoek worden twee benaderingen toegepast om de relaties tussen gezondheidsstoornissen en levensduur te bepalen. Deze benaderingen worden in de overige hoofdstukken van het proefschrift uitgewerkt. De hiertoe gebruikte data waren afkomstig van een populatie van 47 Franse melkveebedrijven met in totaal 4123 melkkoeien.

De eerste benadering (hoofdstuk 2 en 3) betrof het vaststellen van de relaties tussen optreden van ziekte en afvoer. Er werd onderscheid gemaakt tussen vroege afvoer (binnen 45 dagen na afkalven) en late afvoer. In hoofdstuk 2 worden relaties bepaald tussen afvoer en ziekteoptreden in de lopende lactatie. In hoofdstuk 3 wordt dit uitgebreid tot ziekteoptreden in twee opeenvolgende lactaties, als benadering voor het effect van de ziektehistorie op de afvoerbeslissing. Bij de analyse werd gebruik gemaakt van logistische regressie met vroege dan wel late afvoer als binaire (ja/nee) uitkomst variabele. De veertien meest geregistreerde en klinisch waarneembare gezondheidsstoornissen (verwerpen vroeg in de lactatie, afkalfproblemen, afkalven met assistentie, melkziekte, slepende melkziekte, mastitis, tepelbeschadigingen, niet-traumatische uieraandoeningen, aan de nageboorte blijven staan, metritis, cysteuze ovaria en stoornissen aan het verterings-, aan het bewegings- en aan het ademhalingsapparaat) en een subklinisch syndroom (hoog melkcelgetal) werden gebruikt als verklarende variabelen. Hierbij werden de effecten gecorrigeerd voor jaar, maand van afkalven, pariteit, fokwaarde voor melk, actuele produktie (als de hoogste uitslag van de eerste 2 proefmelkingen) en het interval afkalven-laatste inseminatie. Tevens werden interacties tussen de variabelen opgenomen in het model en werd rekening gehouden met het bedrijfseffect door een random effect model toe te passen (binomiale logistische regressie).

De tweede benadering bestond uit het toepassen van survival analyse, teneinde de produktieve levensduur (LPL), gedefinieerd als het aantal dagen tussen de datum van eerste maal afkalven en de datum van afvoer, te verklaren (hoofdstuk 5). Hierbij werd gebruik gemaakt van het proportional hazard model (Cox regressie). Zestien gezondheidsstoornissen (laat in de lactatie verwerpen en de 15 hierboven genoemde stoornissen) werden onderzocht.

De resulterende schatters waren gecorrigeerd voor effecten van bedrijf-jaar-seizoen (beschouwd als random), maand van afkalven, lactatiestadium, lactatienummer, interval afkalven-laatste inseminatie en de niveaus van melkproduktie en vet- en eiwitgehalte. Alle verklarende variabelen die een effect zouden kunnen hebben op de afvoerkans werden gedefinieerd als tijdsafhankelijk.

Het is een gegeven dat lactaties binnen koeien en koeien binnen bedrijven niet op voorhand als onafhankelijk mogen worden beschouwd bij het bepalen van het risico op afvoer als de experimentele eenheid de lactatie is. In hoofdstuk 4 wordt een methode beschreven om het noodzakelijke criterium van onafhankelijke waarnemingen te toetsen. Deze was gebaseerd op herhaalde random selectie van twee opeenvolgende lactaties per koe. Er werd 10 maal een dataset gecreëerd met daarin binnen koeien een random gekozen paar van opeenvolgende lactaties. Deze 10 datasets werden geanalyseerd met behulp van logistische regressie. Een ziekte werd beschouwd als significant gerelateerd aan afvoer indien deze in minstens 4 datasets als belangrijk naar voren kwam. Deze resultaten werden vergeleken met de resultaten van een analyse waarin het criterium van onafhankelijkheid geweld werd aangedaan door in de dataset alle paren van opeenvolgende lactaties op te nemen. Er bleek een goede overeenkomst te bestaan tussen de resultaten van beide analyses hetgeen betekent dat de resultaten beschreven in hoofdstuk 2 en 3 niet beïnvloed worden door het niet rekening houden met het aanwezig zijn van mogelijke afhankelijkheid tussen de waarnemingen.

De resultaten in hoofdstuk 2 tot en met 5 geven aan hoe veehouders, gemiddeld genomen, rekening houden met gezondheidsstoornissen bij afvoerbeslissingen. Uieraandoeningen en vruchtbaarheidsstoornissen waren de belangrijkste ziekten die de levensduur van de melkkoeien beïnvloedden. Mastitis in een vroeg stadium van de lactatie (binnen 90 dagen na afkalven) verhoogde het risico om afgevoerd te worden in een later stadium van de lopende lactatie, maar een lange termijn effect op de levensduur was minimaal (de mediane levensduur werd met 13 dagen bekort indien deze ziekte optrad in de eerste lactatie). Het herhaald optreden van mastitis, zowel binnen als tussen lactaties, had geen extra invloed op LPL. Mastitis tijdens de droogstand had wel een groot effect op de LPL (de mediane levensduur werd met 443 dagen bekort indien deze ziekte optrad tijdens de periode van droogstand na de tweede lactatie). Tepelbeschadigingen en niet-traumatische uieraandoeningen waren geassocieerd met een verhoogd risico op afvoer vroeg in de lactatie en op afvoer in de volgende lactaties (odds ratio's variërend van 3.6 tot 6.0). Het optreden van een tepelbeschadiging had een significante invloed op de levensduur, vooral als deze optrad in de eerste lactatie. De mediane levensduur werd met meer dan een standaard lactatielengte verkort. Verwerpen en relatief laat in de lactatie gesignaleerde metritis (meer dan 42 dagen na afkalven) hadden een grote invloed op het risico om later in de lopende lactatie afgevoerd te worden (odds ratio's variërend van 2.3 tot 6.2). Beide hadden ook een significante negatieve invloed op de LPL (ongeveer 180 dagen), vooral als ze optraden in de eerste lactatie.

Echter, het effect van gezondheidstoornissen op de levensduur bleek lager te zijn dan het effect van melkproduktieniveau en vruchtbaarheid. De kans op afvoer was sterk verhoogd voor laagproductieve dieren en/of voor dieren met een interval afkalven-laatste inseminatie van meer dan 150 dagen. Dieren met een lage fokwaarde voor melkproduktie vormden ook een hoog risicogroep ten aanzien van afvoer.

Hoofdstukken 2 tot 5 concentreren zich op het bepalen van de betekenis van gezondheidsstoornissen op de afvoerbeslissing op dierniveau. Hierbij werd wel met een bedrijfseffect rekening gehouden, maar de oorzaken van dat effect konden niet worden bepaald. Het bedrijfseffect aangaande individuele afvoerbeslissingen, wordt door een complex van determinanten veroorzaakt. Om een indruk te krijgen van de bijdrage van het management van de veehouder aan dat complex werd een onderzoek uitgevoerd dat beschreven is in hoofdstuk 6. Binnen 3 administratieve districten in West-Frankrijk werden 67 veehouders op een semi-directe wijze ondervraagd naar (1) hun visie op afvoer en gerelateerde aspecten (doel van selectie, reproductie, quota en gezondheidsmanagement), (2) hun contacten met andere veehouders en voorlichters, (3) socio-demografische karakteristieken en (4) kenmerken van het produktiesysteem. Een sociale status werd gedefinieerd aan de hand van parameters die aard en frequentie van contacten die iedere veehouder onderhield met beroepsgenoten beschreven. De managementstijlen werden gedefinieerd als specifieke combinaties van doelen en motivaties ten opzicht van het bedrijven van veehouderij. Cluster analyse werd gebruikt ter groepering van veehouders die homogeniteit vertoonden in hun criteria voor afvoer. Vervolgens werden de relaties tussen deze clusters en de management stijlen (als boven gedefinieerd), de productie systemen en de sociologische parameters bepaald.

Vijf groepen van veehouders werden onderscheiden op basis van de criteria voor afvoerbeslissingen, namelijk de 'multi-criteria conventionals', de 'passive traditionals', de 'activists', de 'tolerant voluntarists' en de 'silent traditionals'. Tussen deze groepen varieerden de management stijlen en de sociale status, hetgeen bewijst dat afvoerbeslissingen gedeeltelijk sociologisch gemedieerd worden en beïnvloed worden door de doelen en motivatie van de veehouder ten opzichte van het bedrijven van veehouderij.

Hoofdstuk 2 tot en met 6 laten zien dat veehouders, gemiddeld genomen, rekening houden met het optreden van gezondheidsstoornissen bij de beslissing om een dier wel of niet af te voeren. Het gemiddelde effect van ziekte op levensduur suggereert dat sommige gezondheidsstoornissen een groot economisch belang hebben door vroegtijdige afvoer. In de algemene discussie wordt nader ingegaan op de vraag hoe dit onderzoek kan bijdragen tot het bepalen van het economisch belang van ziekte op individueel niveau. De nadruk wordt daarbij gelegd op de relevantie van een vroege voorspelling van dieren met een hoog risico in termen van gemist toekomstig inkomen. Daarnaast wordt ingegaan op het feit dat de technische en economische consequenties van gezondheidsstoornissen op individueel bedrijfsniveau moeten worden geëvalueerd, teneinde bedrijfsspecifiek te kunnen opereren, ondermeer ten aanzien van gewenste interventies. Er is een lijst van parameters met bedrijfs- en veehouder-specifieke kenmerken opgesteld die bijdragen tot een beter begrip van het werkelijke belang van gezondheid bij de afvoerbeslissing onder specifieke bedrijfsomstandigheden. Tenslotte wordt benadrukt dat in economische beslissingsondersteunende simulatie modellen terdege rekening moet worden gehouden met de sociologische component in het proces dat ten grondslag ligt aan de beslissing tot afvoer.

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CURRICULUM VITAE

François Beaudeau was born on June 1, 1965 in Le Mans, France. In 1983, he received the general certificate of education (Baccalauréat) majoring in Mathematics (série C). After the preparatory courses (classes préparatoires d'entrée aux grandes écoles) (1983-1985), he entered the National Veterinary School of Nantes (Ecole Nationale Vétérinaire de Nantes, France) where he studied during four years (1985-1989). Attached to the unit of Zootechnics and Rural Economics of the National Veterinary School of Nantes as assistant, he received his degree of Doctor in Veterinary Medicine in June 1990. In June 1991, he obtained the degree of the High Institute of Animal Production (Institut Supérieur des Productions Animales, France). Granted by the National Institute of Agronomic Research (Institut National de la Recherche Agronomique), he entered the Unit of Animal Health Management (Laboratoire de Gestion de la Santé Animale) at the National Veterinary School of Nantes in January 1992. During three years, he performed his PhD thesis on the relationships between disease and longevity of dairy cows. He spent several months in the Department of Animal Husbandry of the Wageningen Agricultural University.