A method for describing disease patterns during the life span of dairy cows.

Bernard Faye, R Boulme, Françoise Lescourret, Jean Baptiste Coulon

Bernard Faye, R Boulme, Françoise Lescourret, Jean Baptiste Coulon. A method for describing disease patterns during the life span of dairy cows.. Veterinary Research, 1996, 27 (4-5), pp.453-464. hal-02693600

HAL Id: hal-02693600
https://hal.inrae.fr/hal-02693600v1

Vet Res (1996) 27, 453-464

Original article

A method for describing disease patterns during the life span of dairy cows

B Faye [1]*, R Boulme [1], F Lescourret [1], JB Coulon [2]

[1] *Laboratoire d'écopathologie,*
[2] *Laboratoire d'adaptation des herbivores aux milieux, Inra Clermont-Ferrand-Theix,*
63122 Saint-Genès-Champanelle, France

(Received 2 December 1995; accepted 27 February 1996)

Summary — This study presents some guidelines for describing the health status of dairy cows over their entire life span. It aims to define some types of health-paths (trajectories) described in terms of disease patterns (at the lactation level) and related to cow characteristics (breed, production potential) and farms. The data were collected over a 20-year period on three experimental farms. Eight diseases were analysed: clinical mastitis, lameness, placental retention, foot rot, digestive disorders, milk fever, metritis, and arthritis. The statistical procedures used were correspondence analysis of time-indexed tables and hierarchical ascending clustering. A total of 28 health-paths were identified and 16 of these (the most common) are described in detail. At the lactation level, eight disease patterns were defined: high incidence of disease other than mastitis (1), predominantly mastitis plus milk fever (2), predominantly foot rot (3), very low incidence of disease (4), mastitis plus digestive disorders (5), very high mastitis incidence (6), low incidence of disease (7), foot rot plus digestive disorders (8). Disease patterns 3 and 6 were more common in shorter life spans (≤ 4 lactations). Conversely, health profiles 2 and 4 were generally related to the longest life spans. These results will be included in a future model of the life span of daiy cows which will also take into account other performance parameters such as milk production and reproduction.

dairy cow / life span / health status / culling

Résumé — Une méthode de description des profils de troubles sanitaires à l'échelle de la carrière des vaches laitières. *L'étude présente une approche permettant de décrire le statut sanitaire à l'échelle de la carrière des vaches laitières, afin de déterminer des types de trajectoires sanitaires*

---

* Correspondence and reprints: UR productions animales, Cirad-EMVT, Campus international de Baillarguet, BP 5035, 34032 Montferrier-sur-Lez, France

décrites en termes de profils de santé à l'échelle de la lactation et reliées aux caractéristiques de la vache (race, potentiel de production) et de sa ferme d'origine. Les données proviennent de trois domaines expérimentaux Inra, enregistrées sur une période de 20 ans. Huit pathologies ont été prises en compte : mammites cliniques, boiteries, rétention placentaire, panaris, troubles digestifs, fièvre vitulaire, métrite et troubles articulaires. La procédure statistique a utilisé une analyse des correspondances sur tableaux indicés dans le temps et une classification ascendante hiérarchique. Au total, 28 trajectoires ont été identifiées et 16 (les plus fréquentes) ont été décrites en détail. À l'échelle de la lactation, huit profils de santé ont été définis : forte morbidité à l'exception des mammites (1), mammites + fièvre vitulaire dominant (2), panaris dominant (3), faible incidence pathologique (4), mammite + troubles digestifs (5), forte incidence des mammites (6), faible incidence pathologique à l'exception des boiteries (7), panaris + troubles digestifs (8). Les profils 3 et 6 étaient plus fréquemment associés aux carrières courtes ($\leq$ 4 lactations). À l'inverse, les profils 2 et 4 ont été rencontrés surtout dans les carrières longues. Ces résultats seront inclus dans un futur modèle de carrière des vaches laitières qui prendront en compte d'autres paramètres tels que la production laitière et les performances de reproduction.

vache laitière / carrière / statut sanitaire / réforme

INTRODUCTION

The productive life span of a cow can be considered as the succession of lactations between first calving and culling or death. Health is related to the length of the life span (Beaudeau et al, 1994a) and is a major factor in culling (Beaudau et al, 1993). However, although there are some references to production performance throughout the life span (Gaspardy et al, 1992), most authors have assessed the health status of farm animals only during sections of the life span within lactation or during two consecutive lactations (Dohoo et al, 1983; Dohoo and Martin, 1984; Bigras-Poulin et al, 1990; Faye, 1991). The latter studies showed dependencies between the health status of consecutive lactations, which suggests that specific sequences of diseases may occur throughout the entire life span of cows.

In this study we assumed that the 'health biography' of a dairy cow could be summarized by a succession of lactations each characterized by one of a few possible types of health status ('lactation disease patterns'). Comparisons between cows yielded specific evolutions of the health status ('life health-paths') likely to be controlled partly by cow characteristics and management practices. Particular attention was paid to summarizing the relationships between health biography and longevity. Such an approach does not provide specific technical advice for the culling decision (Seegers et al, 1994), nor does it assess the effect of disease on longevity (Beaudeau et al, 1994b), but it aims to identify life health-paths in order to compare them in the future with life performance-paths (Coulon et al, 1993). We assume that there are proper dynamics of the categories of performances (health, production, reproduction and weight) during the life span. Concerning these dynamics the basic question is: 'Are they controlled by initial conditions (eg, genetics, heifer's rearing) or do they have an acquired logic' Before answering this question therefore it is necessary to describe the dynamics and their interindividual variability. Therefore, in the present paper we propose an original method to describe the cow's health dynamics at the life-span level and to answer the question 'Is the health biograhy of a specific cow unique, or is it possible to identify types of health-paths during the life span?' Considering the source of the data, our remarks will be focused more on the method than on the description of the dynamics.

MATERIALS AND METHODS

Available data

The data originated from the LASCAR data base described by Lescourret et al (1992). These data concerned 1 179 dairy cows (3 851 lactations) managed in three experimental farms of the Institut national de la recherche agronomique, France (Theix (Th), Orcival (Or) and Marcenat (Ma)) over the last 10–20 years (Coulon et al, 1993). The total number of cows recorded in each farm was 538, 306 and 395 respectively, ie, mean herd sizes of 87, 77 and 82 respectively. The farms were located at moderate elevations (800–1 200 m above sea level). The housing period was long (five or six months). The winter diet was mainly based on grass silage, maize silage or hay. The cows were tie-housed in a cowshed. Other management practices differed slightly between farms, so that the variable 'farm' was considered useful to summarize the management practices.

The diseases were recorded with the same method by technicians and coded by means of the checklist of 83 symptoms or diseases. Having gathered these symptoms into a few groups to facilitate the analyses (Faye et al, 1994a), we retained the eight most frequent groups, ie, clinical mastitis, lameness, placental retention, foot rot, digestive disorders, milk fever, metritis and arthritis (table I). It should be possible to propose a ninth group including 'other diseases', but such a heterogeneous group would risk making further interpretation more difficult.

We excluded from the original data base 355 cows whose last lactation lasted less than 150 days, in order to preclude bias caused by decreased probability of observing disease occurrence in lactations shortened by early culling, and to retain preferentially the life spans ended by voluntary culling. We excluded also cows culled for experimentation ($n = 75$).

Cows belonged to five breeds (Montbeliard (M), French Friesian (FF), Holstein (H), Black-Pied crossbreed (BP), and Red-Pied crossbreed (RP). The Montbeliard breed was present only at Marcenat. French Friesian cows were mainly present at Marcenat (70%) and Theix (30%). The Holstein breed was common at Theix (49%) and Orcival (47%). The Black-Pied crossbred was distributed between Marcenat (27%), Theix (42%) and Orcival (31%). Finally, 87% of the Red-Pied crossbreds were present at Orcival. The cows were characterized by their production potential, estimated by their initial production (IP: mean of the 4th, 5th and 6th days of milk production in the first lactation) (Hoden, 1978; Coulon et al, 1989) and by the length of their life span (one to seven lactations). Cows having longer life spans (up to eleven in the data base) were rare; they were thus grouped with cows having achieved seven lactations.

The life health-paths could be partly described by the breed, initial production potential of cows, culling reason and the farm as summary of management practices. Culling reasons were known and divided among eight causes (reproduction, calving disorders, disease, accident, mastitis, milk production, old age and experimentation).

Statistical procedure

In the following, 'lactation health profiles' refers to the occurrence (presence or not) of each of the eight diseases described above in cows during their separate lactations. 'Life health-path' refers to the specific succession of health profiles in cows during their life spans.

Data processing involved: (1) the identification of a few types of life health-paths for a given length of life span; and (2) the identification of the main types of lactation disease patterns during a lactation.

A first strategy had been examined which consisted of defining types of health profiles first by comparing cow lactations independently of the length of the life span, then by determining the succession of the types of lactation health profile during the course of the life span in the second step. This method yielded 34 types of health-paths, which were difficult to interpret (Faye et al, 1994b). Moreover, we considered that it was more relevant to identify the life health-path in a first step and to simplify the information concerning the health status at lactation level in a second step.

We thus decided upon a strategy which included three steps summarized in figure 1.

Table I. Lactational incidence risk (%) of the main groups of diseases in the three experimental French dairy farms (after Faye et al, 1994a).

Code of the disease	*Group of disease*	*Diseases or symptoms involved*	*Mean lactational incidence risk (%)*	*Lactational incidence risk per lactation*						
				1	*2*	*3*	*4*	*5*	*6*	*7 and +*
MAS	Mastitis chronic mastitis	Clinical mastitis	31.7	28.1	30.1	35.0	32.6	40.4	34.8	32.8
FRT	Foot rot	Foot rot	18.0	16.6	17.5	17.8	18.0	19.5	22.6	23.3
DG	Digestive disorders	Indigestion Intestinal occlusion Bloat Foreign body	12.3	11.6	12.4	12.2	14.9	12.3	12.7	8.9
RET	Placental retention	Placental retention	9.6	10.1	8.0	9.3	8.9	10.5	13.2	12.2
MET	Metritis	Metritis Vaginitis	8.4	11.1	8.4	6.7	5.5	7.6	7.2	6.1
LAM	Lameness	Lameness Interdigital hyperplasia Ulceration of the sole Heel horn erosion	7.6	8.6	6.6	7.8	7.3	7.6	7.2	5.6
ART	Arthritis	Arthritis lymphangitis	6.5	11.6	5.6	4.1	3.5	4.0	3.3	1.1
MFR	Milk fever	Milk fever	5.2	1.7	2.2	4.7	8.4	17.3	16.0	8.9

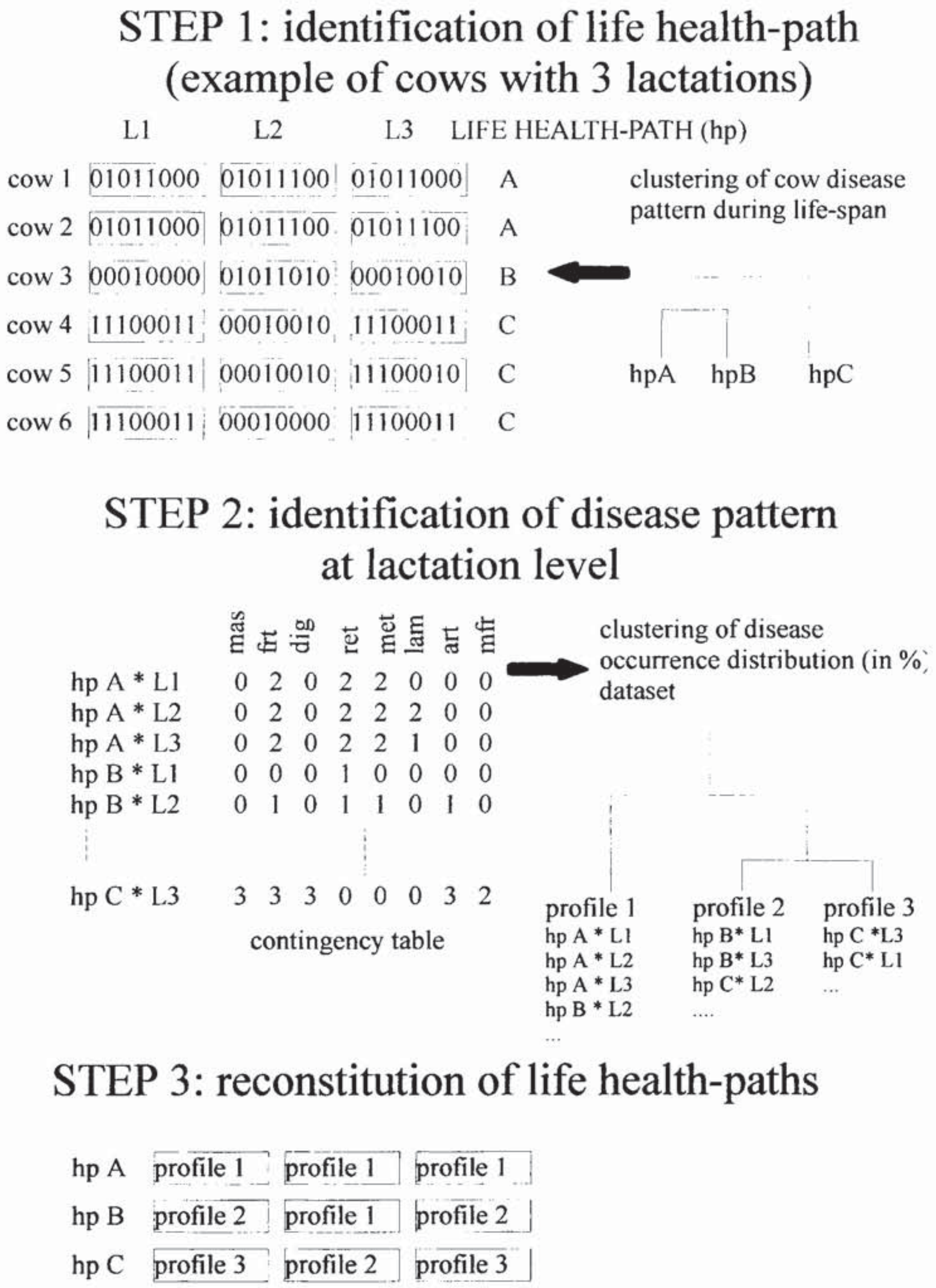

Fig 1. Scheme of the data processing.

Step 1. Assigning a life trajectory to each cow

For a given life-span length (*n* lactations), the data set was arranged as a matrix of rows (cows) and *n* x 8 columns (diseases). Each cell was coded as 0 (absence) or 1 (presence). This coding method was assumed to be sufficient for defining the health status, as generally accepted in epidemiological studies (Dohoo et al, 1983). The data set was analysed by means of correspondence analysis of index-linked time tables (Escofier, 1979; Benzecri, 1984). This analysis was a variant of the factorial correspondance analysis allowing the time-succession of similar data sets to be taken into account (ie, in our case, the sequence of lactations during the course of the life span).

This analysis was followed by a hierarchical ascending clustering (HAC) using the χ^2 distance, in order to identify homogeneous groups of cows with respect to the evolution of health status ('life trajectory'), namely A, B, C... (fig 1). The final number of clusters was chosen according to the method of Critchley (1988), ie, until the gain of variance at each level of clustering decreased suddenly (Faye, 1991). Because we did not wish to describe marginal life trajectories, only the main groups (ie, including at least 20% of the total number of cows for a given life-span length) were retained in the second step. However, these marginal trajectoires will be considered as supplementary data in the next analysis.

Step 2. Assigning a disease pattern to each trajectory x lactation

We assumed that lactations could be compared with respect to diseases independently of cows. Here, each lactation was coded by means of both trajectory (A, B, C,...) and its parity (1, 2, ..., n), namely trajectory x lactation (or health-path x lactation), to prepare the third step (see later).

For each lactation, knowing the trajectory (trajectory x lactation), we calculated the occurrence of the observed diseases (for example the number of the eight defined diseases concerning all the lactation 1 belonging to health-path A). So, we obtained a contingency table crossing trajectory x lactation and diseases. To identify homogeneous types of trajectory x lactation, we used hierarchical ascending clustering on a dataset of health-path lactations described by the occurrence distribution (in %) of the eight diseases. At the close of this analysis, we assigned a number representing the type of disease pattern to each lactation (fig 1).

The mean incidence of the eight diseases was calculated for each type of lactation disease pattern. Obviously, some lactations were free of these diseases. The independence of the lactation of disease pattern was tested by likelihood ratio test (test G) described by Scherrer (1984).

Step 3. Reconstitution of the health-path as a sequence of lactation disease pattern

Each life health-path for a given life span became the sequence of the types of lactation disease pattern defined in the second step (fig 1). The within distribution of breeds, farms, culling reasons and IP was calculated for each life health-path. This data process took into account the real sequences of disease patterns at lactation level during the whole life span in the first step. Subsequent steps were aimed at simplifying the data and helping the interpretation, particularly by removing the marginal life health-paths.

The data management and statistical test used S software (Becker et al, 1988), and the data analysis ADDAD software (Fenelon, 1981).

RESULTS

After step 1, two or three types of trajectory were identified for each length of life span, after those concerning only a restricted number of cows were removed. These clusters explained 57–66% of the total variance of the data set as the life-span length. Overall, 16 life health-paths were retained out of 28. A few healthpaths were characterized by the absence of disease over the whole life span. But none of these 'healthy' health-paths concerned more than 20% of the cows for a given longevity except the shortest (one lactation only). Alternatively, a 'healthy' health-path could be affected by diseases other than the eight retained.

Lactation disease pattern

Before describing the identified life health-path, we present the lactation disease patterns (table II). These eight patterns explained 70% of the variance of the data set. The likelihood ratio test using the experimentwise error rate (α_e) confirmed the heterogeneity of the distributions of diseases in the eight lactation health profiles ($P <$ 0.01). However, the statistical diffference between profiles 2 and 5 was just beyond the significance threshold (0.05). Mastitis was prefominant in profiles 2, 5 and 6. In profiles 3 and 8, foot rot was predominant. It was associated with mastitis and digestive disorders in profile 8 but not in profile 3. Profile 1 was characterized by a high incidence risk of digestive disorders, metritis, lameness and arthritis.

Table II. Mean incidence risk (%) of the eight dairy cow diseases in the disease patterns identified at the lactation level in three French herds. The profile are reordered according to their maximum heterogeneity (G Test using experimentwise error rate).

Lactational disease pattern	disease							
	mas	frt	dig	ret	met	lam	art	mfr
8 ▒	**38**	**57**	**23**	3	2	0	15	0
6 ▓	**55**	7	14	13	15	4	8	**0**
5 ▦	**51**	6	**25**	9	17	18	6	**14**
2 ■	**49**	17	20	12	9	9	5	**17**
4 ░	30	14	9	8	7	6	5	6
3 ░	17	**47**	3	9	1	1	2	2
7 ▓	34	22	7	3	13	16	17	2
1 □	10	22	**43**	12	**35**	**37**	**33**	0

mas: mastitis; frt: foot rot; dig: digestive disorder; ret: placental retention; met: metritis; lam: lameness; art: arthritis; mfr: milk fever.

Life health-path

The succession of these profiles in the different life health-paths are reported in figure 2, and the characteristics are summarized in table III. The dominance of profiles 4 (low disease risk) and 2 (mastitis associated with milk fever) was obvious in life spans of over four lactations. In contrast, many 6 (high risk of mastitis) or 3 (high risk of foot rot) profiles were encountered in shorter life spans. In the following description, we assumed that the experimental farms could be considered as being typical in general management practices.

The most frequent health-path (C1) was characterized by profile 1 where several diseases had a high incidence; this profile was restricted to this health-path. Health-path A1 (mastitis dominant) represented all of the one-lactation cows culled for mastitis. Health-path B1 (foot-rot dominant) was characteristic of the Marcenat farm. In health-paths with two lactations, the lactations were characterized by foot rot and mastitis, and both paths have the same profile (intermediate mastitis risk) in lactation one.

We observed a visual difference between life spans of less than four lactations and longer life spans. Indeed, we observed eleven lactations with profile 2 amongst the longer life spans vs zero amongst the short ones, and 23 lactations with profile 4 amongst the long life spans vs 1 amongst short ones. A few life spans were characterized by the recurrence of the same profile with a predominant disease such as mastitis or foot rot. Foot-rot recurrence (F3, H4) was more common in French Friesian cows from Marcenat. These recurrences were also observed in Montbeliards but they did not affect longevity as for the French-Friesians (N7).

The life spans with mastitis recurrences (G3 and I4) characterized Holstein cows from Theix and Orcival. Life health-paths with mastitis plus milk-fever recurrences were more common in long life spans (≥ 5 lactations) and were rather associated with cows from Theix. There was no difference between the life health-paths according to the initial production.

Concerning the marginal health-paths, we observed the same difference between long and short life cycles. For life cycles of over four lactations, all the lactation disease patterns were number 4 (low disease incidence). The two marginal health-paths of four lactations comprised a succession of lactation profile number 3 (foot rot). For the shortest health-paths, profiles 3, 6 and 7 were predominant but with different sequences than those previously described.

DISCUSSION

The first point is that with the proposed method it is possible to identify 'health biography' common to several dairy cows.

Even if the main culling reasons in our trials were infertility or insufficient milk production, as commonly assessed (Milian-Suazo et al, 1989), disease patterns were associated with culling decisions. These decisions depend not only on the type of diseases experienced by the cow but also on the associations between diseases (Beaudeau et al, 1993). Indeed, in shorter life spans (up to four lactations), disease-incidence risks were higher than in comparable lactations of cows with longer life spans. The most unfavourable health profile (profile 1) was encountered only in cows that were culled without a second lactation.

Some health-paths were characterized by the recurrence of disease patterns. The recurrence of clinical mastitis has been observed by many authors (Dohoo and Martin, 1984; Schukken et al, 1988; Bigras-Poulin et al, 1990), but over two consecutive lactations only. However, a true association

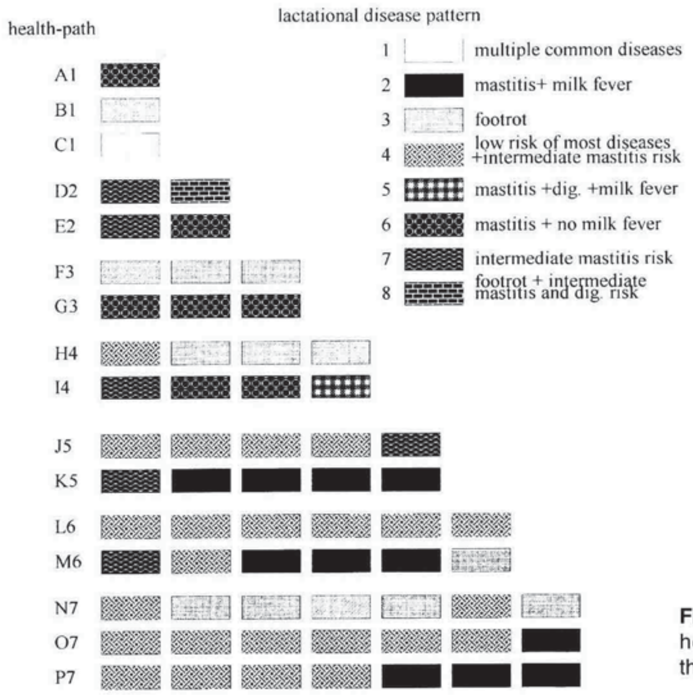

Fig 2. Description of the life health-paths according to the length of the life-span.

Table III. Characteristics of the main life health-path from the analysis of records of three French dairy herds.

Length of the life-cycle	*Code of the health-path*	n	*Cows for a given length of life-cycle (%)*	*Main breeds (% of cows for the health path)*	*Main farms (% of cows for the health path)*	*Mean ± SD initial production (in kg) in L1*	*Main health culling reason*	*Cows culled (in % of reason)*
1	A1	45	35	RP = 20 BP = 20	Ma = 42 Th = 31	15.1 ± 3.5	Mastitis	100
	B1	30	23	M = 47 FF = 33	Ma = 77	14.1 ± 2.9	Calving difficulties	67
	C1	51	39	H = 47 Or = 39	Th = 43	14.9 ± 3.1	Other disease	50
2	D2	60	40	FF = 47	Ma = 60	14.5 ± 4.1	Other disease Mastitis	68 50
	E2	53	35	H = 42	Th = 49 Or = 42	15.2 ± 3.3	Mastitis Calving	43 100
3	F3	31	22	M = 27 FF = 51	Ma = 75	16.6 ± 3.6	Other disease	58
	G3	87	61	H = 36	Th = 47	14.9 ± 3.9	Mastitis	75
4	H4	27	26	FF = 59	Ma = 93	13.9 ± 2.4	No main reason	–
	I4	65	64	M = 18 H = 32 RP = 11 BP = 17	Or = 43 Th = 29	15.4 ± 4.3	Mastitis	78
5	J5	16	22	H = 37 Th = 38	Or = 38	14.3 ± 4.1	No main reason	–
	K5	36	49	H = 36 FF = 25 RP = 14	Th = 44	15.5 ± 4.3	Mastitis	57
6	L6	16	29	M = 62	Ma = 56	14.9 ± 2.5	No main reason	–
	M6	29	52	H = 38 FF = 61	Th = 52	14.9 ± 3.7	Other disease Mastitis	50 63
7	N7	32	43	M = 59	Ma = 94	13.2 ± 4.2	Other disease	57.2
	O7	18	24	BP = 33	Th = 44	14.5 ± 2.9	Mastitis	37.5
	P7	22	29	No main breed	Th = 50	14.6 ± 2.9	No main reason	–

M = Montbeliarde; FF = French Friesian; H = Holstein; RP = Red Pied Crossbreed; BP = Black-Pied crossbreed; Ma = Marcenat; Or = Orcival; Th = Theix.

for any pair of subsequent lactations implies that this association is true also at the life-span level. Genetic predispositions may be envisaged (Syväjärvi et al, 1986) and also environmental effects. The recurrence of lameness has also been described for two consecutive lactations (Dohoo and Martin, 1984; Rowlands et al, 1986). The heritability of some foot disorders such as foot rot might be quite large (0.39 according to Smit et al, 1986).

In longer life spans, health profile 2 (high incidence of mastitis and milk fever) was common from the second lactation onwards. Milk fever affects mostly multiparous (Larvor et al, 1961) and high-yielding cows (Payne, 1983). This latter point could explain the great longevity of these cows. Indeed, one could suppose that their milk production takes first place in culling decisions despite a high mastitis incidence.

Usually primiparous cows are less affected by production diseases such as placental retention (Thompson et al, 1983), metritis (Erb and Martin, 1980), mastitis and lameness (Dohoo et al, 1984). Thus, health profiles with low disease incidences (4 and especially 7) were more common in first lactations of all paths than in other lactations.

The exclusion in our study of cows with shortened lactations might introduce some bias if there were effects of diseases on early culling. But, precisely, we assumed that only life spans with mostly voluntary culling could be easily interpreted. In the case of shortened lactations, there was a risk of the current disease pattern changing, in part independently of previous lactation disease pattern. In most of the cases, early culling was associated with healthy disorders and was an involuntary decision (Beaudeau et al, 1994c).

The relationships between some health-paths and experimental farms could be due to several factors. First, some management practices differed between farms, such as, for example, hoof trimming which was only curative at Theix and Marcenat, but preventive at Orcival. Second, the breed composition of the herds was different: Montbeliard cows were present at Marcenat only, Holstein cows dominated at Theix and Orcival, French-Friesian cows were more common at Marcenat and crossbreed cows at Orcival (Coulon et al, 1993). Third, the animal housing and general feeding systems were different between the three farms. At Marcenat, for example, tied housing included short stalls which represented a risk factor for lameness (Maton, 1987).

Therefore, farm and breed were obviously confounding factors. However, our objective was precisely to describe the life health-path in the light of these variables, not to adjust for herd and breed, in order to compare the 'health performance' with zootechnical performance in real farming systems (Landais, 1991).

However, the peculiarities of these experimental farms do not allow generalization of the present observations to other farms, especially private ones; nevertheless, some comparisons within-herd or within-breed can be made. For example, in the Marcenat farm where the lactational foot rot incidence risk was 29.2% (Faye et al, 1994a), French Friesian cows were more affected (41.9%) than Montbeliard cows (24.6%). In this farm, 23 cows belonged to the life health-path F3, and 25 to the health-path H4, characterized by recurrence of foot rot. F3 described eleven French Friesian cows but only six Montbeliards. In H4, the numbers were 16 and 8 respectively, confirming the higher susceptibility of the Friesian breed to lameness.

In the same way, the lactational mastitis incidence risk was 48.2% in Holstein at Theix and 28.5% in Holstein at Marcenat. In spite of the same number of Holstein cows at these two farms (162 at Theix and 158 at Orcival), the proportion of Holstein cows belonging to life health-paths characterized by recurrence of mastitis (K5, M6, P7) was twice as large at Theix as at Orcival, confirming the difference in farming practices.

However, although the proposed method takes into account the time effect for a particular cow, it does not allow consideration of the time effect at farm level. We assume that the disease-recording system was similar over 20 years, but we do not have any idea of the interactions between cows and we cannot assume the changes in lactation disease patterns for a given lactation over 20 years.

A way of modelling the life span of dairy cows using the Markov chain method (Carpenter, 1988; Jalvingh et al, 1992), which is a long-term objective of the scientific programme at the origin of the data base LASCAR (Coulon et al, 1993), might be to consider the types of trajectories followed by cow performance or health. The life span could be considered as the succession of different statuses defined at lactation level by these performances. The present study was along these lines and aimed to analyse a part of this chain. Of course, the validation of such a model will be one of the essential steps.

REFERENCES

Beaudeau F, Henken A, Fourichon C, Frankena K, Seegers H (1993) Associations between health disorders and culling of dairy cows: a review. *Livest Prod Sci* 35, 213-236

Beaudeau F, Ducrocq V, Fourichon C, Billon D, Seegers H, Noordhuizen JP (1994a) Effect of udder disorders on length of productive life of Holstein dairy cows assessed by survival analysis. *Proc VIIth Ind Symp Vet Epidemiol Econ 15–19 August 1994, Nairobi (Kenya), The Kenya Vet* 18, 173-176

Beaudeau F, Ducrocq V, Fourichon C, Faye B, Seegers H (1994b) Impact des troubles de santé sur la longévité des vaches laitières. *Renc Rech Ruminants* 1, 261-264

Beaudeau F, Frankena K, Fourichon C, Seegers H, Faye B, Noordhuizen JP (1994c) Associations between health disorders of French dairy cows and early and late culling within the lactation. *Prev Vet Med* 19, 213-231

Becker RA, Chambres JM, Wilks RA (1988) *The new S language. A programming environment for data analysis and graphics* (JM Chambres, TJ Hatic, eds), Wadworth & Brooks/Cole. Computer Science Series, CA, USA, 702 p

Benzecri JP (1984) *Pratique de l'analyse des données.* Dunod, Paris, 456 p

Bigras Poulin M, Meek AH, Martin SW (1990) Interrelationships among health problems and milk production from consecutive lactations in selected Ontario Holstein cows. *Prev Vet Med* 8, 15-24

Carpenter TE (1988) Microcomputer programs for Markov and modified Markov chain disease models. *Prev Vet Med* 5, 169-179

Coulon JB, Hoden A, Faverdin P, Journet M (1989) Dairy cows in ruminant nutrition. In: *Recommended Allowances and Feed Tables.* (J Libbey, ed), London, UK, 73 p

Coulon JB, Faye B, Landais E, Lescourret F, Pérochon L, Troccon JL (1993) Description de la base de données «Lascar», un outil pour l'étude des carrières des vaches laitières. *INRA Prod Anim* 6, 151-160

Critchley F (1988) The euclidean structure of a dendogram, the variance of a node and the question "How many clusters really are there?" In: *Classification and Related Methods of Data Analysis. Proceedings of the first conference of the International Federation of Classification Societies, 29 June–1 July 1987, University of Aachen, Aachen, Germany* (H Bock, ed), Elsevier, Amsterdam, 75-85

Dohoo IR, Martin SW (1984) Disease, production and culling in Holstein–Friesian cows. III. Disease and production as determinants of disease. *Prev Vet Med* 2, 671-690

Dohoo LR, Martin SW, Meek AM, Sandals WCD (1983) Disease, production and culling in Holstein–Friesian cows. I. The data. *Prev Vet Med* 1, 321-334

Dohoo IR, Martin SW, McMillan I, Kennedy BW (1984) Disease, production and culling in Holstein-Friesian cows. 2. Age, season and sire effects. Prev Vet Med 2, 655-670

Erb HN, Martin SW (1980) Interrelationships between production and reproductive diseases in Holstein cows. Age and seasonal patterns. *J Dairy Sci* 63, 1918-1924

Escofier B (1979) *Stabilité en analyse factorielle.* PhD thesis, University of Paris-VI

Faye B (1991) Interrelationships between health status and farm management system in French dairy herds. *Prev Vet Med* 12, 133-152

Faye B, Landais E, Coulon JB, Lescourret F (1994a) Incidence des troubles sanitaires chez la vache laitière : bilan de 20 années d'observation dans 3 troupeaux expérimentaux. *INRA Prod Anim* 7, 191-206

Faye B, Duc D, Landais E, Coulon JB, Lescourret F (1994b) Types de trajectoire du statut sanitaire au cours de la carrière des vaches laitières. *Vet Res* 25, 300-304

Fenelon JP (1981) *Qu'est-ce que l'analyse de données ?* Lefonen, Paris

Gaspardy A, Szücs E, Dohy J, Bozo S (1992) Relation of life performance to various lactation yields at different parities in dairy cows of high longevity. In: *43rd Annual meeting of the EAAP* (RD Politick, ed), 14–17 Sept 1992, Madrid, Spain

Hoden A (1978) Rationnement en début de la lactation. In: *La vache laitière.* INRA, Paris, France, p 71

Jalvingh AW, Dijkuizen AA, Van Arendonk JAM (1992) Dynamic probabilistic modelling of reproduction and replacement management in sow herds. General aspects and model description. *Agric Syst* 39, 133-152

Landais E (1991) Écopathologie et systémique. *Etud Rech Syst Agraires Dev* 21, 5-11

Larvor P, Brochart M, Theret M (1961) Enquête sur la fièvre vitulaire et la tétanie d'herbage des bovins en France. *Econ Med Anim* 2, 5-30

Lescourret F, Coulon JB, Faye B, Landais E, Perochon L (1992) Modelling an information system using the MERISE method for agricultural research: the example of a database for a study of performances in dairy cows. *Agric Syst* 38, 149-173

Maton A (1987) The influence of the housing system on claw disorders with dairy cows. Cattle housing systems, lameness and behaviour. In: *Proc of a seminar on the influence of the design of housing systems for cattle on lameness and on behaviour* (E Wierenga, DJ Peterse, eds), CEE, Brussels, 151-158

Milian-Suazo F, Erb HN, Smith RD (1989) Risk factors for reason-specific culling of dairy cows. *Prev Vet Med* 7, 19-29

Payne JM (1983) La fièvre de lait ou parésie puerpérale. In: *Les maladies métaboliques des ruminants domestiques.* Point Vétérinaire, Maisons-Alfort, 41-58

Rowlands GJ, Lucey S, Russel AM (1986) Susceptibility to disease in the dairy cow and its relationships with occurrences of other diseases in the current of preceeding lactation. *Prev Vet Med* 167, 105-111

Schukken YH, Erb HN, Smith R (1988) The relationship between mastitis and retained placenta in a commercial population of Holstein dairy cows. *Prev Vet Med* 5, 181-190

Scherrer B (1984) *Biostatistique.* Gaëtan Morin, Chicoutimi, Canada

Seegers H, Fourichon C, Mahler X, L'Hostis M (1994) A framework for animal health management. *Vet Res* 25, 165-173

Smit H, Verbeek B, Peterse DJ, Jansen J, McDaniel BT, Politiekk RD (1986) Genetic aspects of claw disorders claw measurements and 'type' scores for feet in Friesian cattle. *Livest Prod Sci* 15, 205-217

Syväjärvi J, Saloniemi H, Gröhn Y (1986) An epidemiological and genetic study on registered diseases in Finnish Ayrshire cattle. IV. Clinical mastitis. *Acta Vet Scand* 27, 223-234

Thompson JR, Pollak EJ, Pellisier CL (1983) Interrelationships of parturition problems, production of subsequent lactation, reproduction and age at first calving. *J Dairy Sci* 66, 1119-1127