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Loser cows in Danish dairy herds with loose-housing systems: Definition, prevalence, consequences and risk factors

Peter T. Thomsen

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Loser cows in Danish dairy herds with loose-housing systems: Definition, prevalence, consequences and risk factors

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Cover photo: Illustrates the expected relationship between dead cows and loser cows. It is hypothesised that the dead cows might be considered as a subset of the loser cows.

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Preface

This PhD thesis is intended to fulfil the requirements for the PhD degree at the Royal Veterinary and Agricultural University, Copenhagen, Denmark. The research was carried out from 2002 to 2005, mainly at the Department of Animal Health, Welfare and Nutrition, Danish Institute of Agricultural Sciences, Research Centre Foulum.

During the entire process of writing this thesis, I have tried always to keep the word ‘concise’ in mind. I have tried to avoid using too many words as it is my belief that the essence of my work is best communicated in a concise way.

An overall objective of the project has been that the results should preferably be usable at commercial dairy farms. Research in itself may be both exciting and stimulating. However, an additional goal of research – in my opinion - is to make the results of the research usable in ‘real life’. Therefore, it is my hope that this work can and will be used to benefit Danish dairy cows and farmers.

During the course of the project a number of people have inspired and supported me. I would like to thank Finn Strudsholm, Danish Cattle Federation, my supervisor Hans Houe, the Royal Veterinary and Agricultural University, my co-supervisor Jan Tind Sørensen, Danish Institute of Agricultural Sciences and Søren Østergaard, Danish Institute of Agricultural Sciences. You have all been a great help and support during the entire course of the project. I would also like to express my gratitude to Anne Mette Kjeldsen, Danish Cattle Federation, who has introduced me to the Danish Cattle Database, and Annette Kjær Ersbøll, the Royal Veterinary and Agricultural University, who has patiently answered countless questions about statistics. The Danish dairy farmers, who participated in the project, are thanked for their co-operation and hospitality. I am grateful for all the friendship and support from my colleagues at the Research Unit of Herd Health and Production Management, Department of Animal Health, Welfare and Nutrition, Danish Institute of Agricultural Sciences.

Last, but not least, I would like to thank my family for their support. My wife Helle and our daughters Laura and Katrine are always there for me and have helped me keep things in the right perspective. I might be very fond of cows, but it is nothing compared to Helle and Laura. They also claim that they know more about cows than I do.

Peter T. Thomsen

Foulum, September 2005

Parts of the results from the project has been presented in 5 articles/manuscripts:

Paper I: Thomsen, P. T., A. M. Kjeldsen, J. T. Sørensen, and H. Houe. 2004. Mortality (including euthanasia) among Danish dairy cows (1990-2001). Preventive Veterinary Medicine 62: 19-33.

Paper II: Thomsen, P. T., A. M. Kjeldsen, J. T. Sørensen, H. Houe, and A. K. Ersbøll. 2005. Herd level risk factors for cow mortality in Danish dairy cattle herds. Veterinary Record, in press.

Paper III: Thomsen, P. T., and N. P. Baadsgaard. 2005. Validation of a protocol for clinical examination of dairy cows. Submitted.

Paper IV: Thomsen, P. T., S. Østergaard, J. T. Sørensen, and H. Houe. 2005. Loser cows in Danish dairy herds: Definition, prevalence and consequences. Submitted.

Paper V: Thomsen, P. T., S. Østergaard, H. Houe, and J. T. Sørensen. 2005. Loser cows in Danish dairy herds: Risk factors. Submitted.

In the following these articles/manuscripts are referred to by their numbers (paper I, II, III, IV and V).

Summary

During the last few years, many Danish dairy farmers have expressed increasing concerns about a new group of cows, which we have chosen to term 'loser cows'. A loser cow is for different reasons not able 'to keep up with' the rest of the cows in the herd. A loser cow has until now not been characterised scientifically.

Many loser cows die or are euthanised. The dead cows might therefore be considered as some sort of 'top of the iceberg' concerning the loser cows. The first part of the project focussed on mortality among Danish dairy cows. Data from the Danish Cattle Database was used to evaluate the mortality among Danish dairy cows during the years 1990 to 2001. During this period, mortality risk approximately doubled (from approximately 2 % in 1990 to approximately 4 % in 2001). Mortality risk has increased for all age groups over the years, but the mortality risk among older cows (parity 3 or older) is approximately twice the mortality risk among younger cows. A high proportion of deaths occur during the first 30 days of the lactation. A questionnaire survey was used to evaluate the proportion of euthanised cows, the development over time in the proportion of euthanised cows and the primary reasons for death or euthanasia. The replies showed that 58 % of the dead cows were euthanised and 42 % died unassisted. Furthermore, the replies indicated that the proportion of euthanised cows had increased. More than half of the farmers stated that they euthanised relatively more cows in 2002 than five years earlier. The most frequent primary reason for death or euthanasia were locomotor disorders, which accounted for 25 % of all deaths.

Data from the Danish Cattle Database was used to evaluate mortality risk at the herd level for the period 1st October 2000 to 30th September 2001. All Danish dairy herds participating in milk recording (N=6,839) were included in the study. Mortality risk at the herd level varied considerably among herds. Mean mortality risk for the first 100 days of the lactation was 2.5 %. Some herds had a low mortality whereas others had a very high mortality. In total, 27 % of the herds had no dead cows during the year studied, whereas more than 10 % of the herds had a mortality risk during the first 100 days of the lactation exceeding 5 %.

A number of herd level risk factors for cow mortality was identified. Mortality risk at the herd level increased with increasing herd size, increasing proportion of purchased cows, and increasing average somatic cell count at the herd level. Mortality risk decreased with increasing average milk yield per cow. The risk was low in free stall barns with deep litter compared to those with cubicles and tie stall barns. Herds comprising Danish Holstein or Danish Jersey as the predominant breed had a higher mortality risk than those comprising Danish Red Dairy Breed. Mortality risk was lower in organic herds compared to conventional herds and in herds that were pasture grazed during the summer. The risk factors all had a relatively large effect on the predicted mortality risk in the herd.

We studied loser cows in 39 Danish commercial dairy herds with loose-housing systems. The herds were selected randomly among herds that met certain inclusion criteria (e.g. more than 100 cows, primarily Danish Holstein, cows being milk recorded and conformation scored). Each herd was visited three times with an interval of approximately 120 days during the period September 2003 to October 2004. During each visit, nearly all cows in the herd (both lactating cows and dry cows) were examined. We developed a clinical protocol for the examination of the cows and a loser cow was defined on the basis of this clinical examination. The clinical signs included in the protocol were lameness, body condition, hock lesions, other cutaneous lesions, vaginal discharge, skin condition and general condition. The results of the clinical examination were converted into a loser

cow score. In this way, each cow observed was assigned a loser cow score ranging from 0 to 32. Cows with a loser cow score of 8 or more were classified as loser cows. A total of 15,151 cows from the 39 herds were observed and assigned a loser cow score. The overall prevalence of loser cows among these cows was 3.24 %. The prevalence of loser cows in the 39 herds ranged from 0 % to 11.5 %.

The loser cow state has a number of negative consequences for the farmer and for the cow. Loser cows has decreased milk production and increased mortality and morbidity compared to non loser cows. Compared to non loser cows, loser cows are more often culled in an 'unfavourable way' and the farmers generally assessed that the loser cows caused an increased workload compared to non loser cows.

The relation between the new 'diagnosis' loser cow and lameness was evaluated and it was concluded that a loser cow is different from, and more than just, a lame cow.

Based on data from the Danish Cattle Database and data collected during herd visits we evaluated risk factors for loser cows at the cow level and at the herd level. Herds with a high average somatic cell count, a high calf mortality, many stillborn calves, hard cubicles and no grazing seem to be associated with a high proportion of loser cows. Additionally, older cows seem to be at greater risk than younger cows. Based on the evaluation of risk factors, strategies for the prevention of loser cows were discussed.

The clinical protocol has been evaluated regarding intra- and inter-observer agreement. The loser cow score (and in particular a simplified version of the loser cow score) is relatively quick and easy to use.

Sammendrag

Gennem de sidste få år har danske mælkeproducenter udtrykt stigende bekymring for en ny gruppe af køer, som vi har valgt at kalde "taberkøer". Af forskellige årsager er en taberko ikke i stand til at klare sig i konkurrencen med besætningens øvrige køer. En taberko har indtil nu ikke været defineret videnskabeligt.

Mange taberkøer dør eller bliver aflivet. De døde køer kan derfor betragtes som "toppen af isbjerget" med hensyn til taberkoproblematikken. Den første del af projektet fokuserede på dødelighed blandt danske malkekøer. Data fra Kvægdatabasen blev brugt til at undersøge dødeligheden blandt danske malkekøer i årene 1990 til 2001. Dødeligheden (mortality risk) blev i denne periode fordoblet (fra ca. 2 % i 1990 til ca. 4 % i 2001). Dødeligheden er steget for alle aldersgrupper gennem årene, men dødeligheden blandt ældre køer (3. kalvs eller ældre) er tilnærmelsesvis dobbelt så høj som dødeligheden blandt yngre køer. En stor andel af samtlige dødsfald sker i løbet af de første 30 dage efter kælvning. En interviewundersøgelse blev brugt til at undersøge andelen af aflivede køer, udviklingen i andelen af aflivede køer over tid og de primære årsager til død eller aflivning. Svarene viste, at 58 % af de døde køer var aflivede og 42 % selvdøde. Andelen af aflivede køer er sandsynligvis steget, idet mere end halvdelen af landmændene erklærede, at de aflivede relativt flere køer i 2002 end fem år tidligere. Den hyppigste årsag til død eller aflivning var klov-/lemmelidelser, som var den primære årsag i 25 % af samtlige dødsfald.

Data fra Kvægdatabasen blev brugt til at undersøge dødeligheden på besætningsniveau i perioden 1. oktober 2000 til 30. september 2001. Alle ydelseskontrollerede besætninger (N=6.839) var med i undersøgelsen. Dødeligheden på besætningsniveau varierede meget fra besætning til besætning. Den gennemsnitlige dødelighed for de første 100 dage af laktationen var 2,5 %. Nogle besætninger havde en lav dødelighed, mens andre havde en meget høj dødelighed. Totalt set havde 27 % af besætningerne ingen døde køer i løbet af det år undersøgelsen omfattede, mens mere end 10 % af besætningerne havde en dødelighed i løbet af de første 100 dage af laktationen på over 5 %.

En række risikofaktorer for dødelighed på besætningsniveau blev identificeret. Dødeligheden på besætningsniveau steg med stigende besætningsstørrelse, stigende andel af indkøbte køer og stigende celletal på besætningsniveau. Dødeligheden faldt, når den gennemsnitlige mælkeydelse i besætningen steg. Dødeligheden var lav i løsdriftsstalde med dybstrøelse sammenlignet med sengebåsestalde og bindestalde. Besætninger med SDM Dansk Holstein eller Jersey som den dominerende race havde en højere dødelighed end besætninger med RDM. Dødeligheden var lavere i økologiske end i konventionelle besætninger og i besætninger, hvor køerne kom på græs om sommeren. Alle risikofaktorer havde en relativt stor effekt på den predikterede dødelighed i besætningen.

Vi studerede taberkøer i 39 danske malkekvægsbesætninger med løsdriftssystemer. Besætningerne blev udvalgt tilfældigt blandt besætninger, som opfyldte visse krav (f.eks. mere end 100 årskøer, primært SDM Dansk Holstein, deltagelse i ydelseskontrol og besætningskåring). Hver enkelt besætning blev besøgt tre gange med ca. 120 dages mellemrum i perioden september 2003 til oktober 2004. Ved hvert besøg blev næsten samtlige køer i besætningen (både malkende køer og goldkøer) undersøgt. Vi udviklede en klinisk undersøgelsesprotokol til undersøgelsen af køerne, og en taberko blev defineret på basis af denne kliniske undersøgelse. Undersøgelsesprotokollen omfattede de kliniske symptomer halthed, huld, haselæsioner, andre hudlæsioner, vaginalflåd, hud/hårlag og almenbefindende. Resultaterne fra den kliniske undersøgelse blev efterfølgende

omregnet til en taberkoscore. På denne måde fik alle undersøgte køer tildelt en taberkoscore, som kunne variere fra 0 til 32. Køer med en taberkoscore på 8 eller mere blev klassificeret som taberkøer. 15.151 køer fra de 39 besætninger blev undersøgt og tildelt en taberkoscore. Prævalensen af taberkøer blandt disse køer var 3,24 %. Prævalensen af taberkøer i de 39 besætninger varierede fra 0 % til 11,5 %.

Taberkotilstanden har en række negative konsekvenser for landmanden og for koen. Taberkøer har nedsat mælkeydelse, øget dødelighed og øget sygelighed sammenlignet med ikke-taberkøer. Taberkøer udsættes oftere end ikke-taberkøer fra besætningen på en "uhensigtsmæssig" måde og landmændene vurderede generelt, at taberkøerne medførte en øget arbejdsbyrde sammenlignet med ikke-taberkøer.

Sammenhængen mellem den nye "diagnose" taberko og halthed blev undersøgt og konklusionen var, at en taberko er forskellig fra – og mere end blot – en halt ko.

Baseret på data fra Kvægdatabasen og data indsamlet i forbindelse med besætningsbesøg blev risikofaktorer for taberkotilstanden på ko- og besætningsniveau undersøgt. Besætninger med et højt gennemsnitligt celletal, en høj kalvedødelighed, mange dødfødte kalve, sengebåse med hårdt underlag og ingen sommergræsning var associeret med en stor andel af taberkøer. Yderligere så det ud til, at risikoen var højere hos ældre køer end hos yngre køer. Med udgangspunkt i undersøgelsen af risikofaktorer blev strategier til forebyggelse af taberkøer diskuteret.

Den kliniske undersøgelsesprotokol er blevet evalueret vedrørende intra- og inter-observer agreement. Taberkoscoren (og i særdeleshed en forenklet version af taberkoscoren) er relativt nem og hurtig at bruge.

1. Introduction

Danish dairy production has undergone considerable structural changes during the last decade with creation of larger, but fewer herds. From 1994 to 2004 the number of dairy herds has decreased from approximately 16,000 to 6600 and at the same time the average number of cows per herd has doubled to 90 cows per herd in 2004. The percentage of dairy farms with more than 100 cows has increased from approximately 2.5 % in 1991 to 22 % in 2002. Since the mid-nineties an increasing number of new cattle houses have been built. More than 70 % of the Danish dairy cattle population are now being housed in loose-housing systems, many of which have been built during the last few years. New technique used for milking (automatic milking systems), feeding and surveillance has been introduced. At the same time the average milk yield per cow has increased and the number of man hours per cow has decreased (Barrett, 2004). This means that cows tend to be housed in larger groups with increased demands on cow mobility and with less manual attention to the individual cow.

During the last few years, many Danish dairy farmers have expressed increasing concerns about a new group of cows, which we have chosen to term ‘loser cows’. A loser cow is for different reasons not able ‘to keep up with’ the rest of the cows in the herd. Farmers typically complain about increasing morbidity and mortality, decreased milk production, decreased animal welfare and extra workload. Interviews conducted at the beginning of this project showed that most farmers could give their own definition of a loser cow and point out loser cows in their herd. However, a loser cow has until now not been characterised scientifically. A scientifically based definition is necessary in order to quantify the problem, to identify risk factors and eventually reduce the number of future cases.

Many loser cows die or are euthanised. It may therefore be appropriate to consider the dead cows as some sort of ‘top of the iceberg’ concerning the loser cows. Not all loser cows end up dying. Some of the loser cows are sent to slaughter (albeit often with low quality and amount of meat as the result) and some dead cows cannot fairly be termed loser cows (e.g. a healthy, high producing cow that has never experienced any problems until she falls on the slatted floor, fractures a leg and is euthanised). Nevertheless, it is hypothesised that the relationship between loser cows and dead cows may be illustrated as in Figure 1.1.

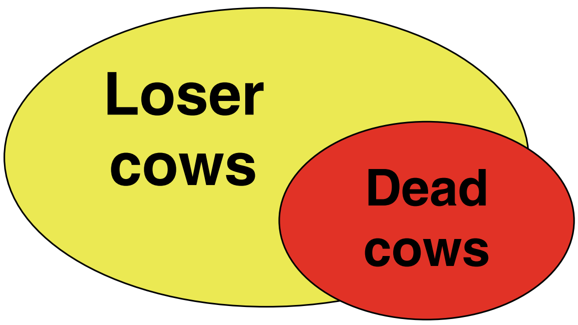

Figure 1.1. Illustration of the expected relationship between dead cows and loser cows. It is hypothesised that the dead cows might be considered as a subset of the loser cows.

Mortality among dairy cows is therefore found relevant in relation to loser cows. Until now mortality among Danish dairy cows has only been sparsely investigated (Nørgaard et al., 1999; Andersen and Lauritsen, 2002). Furthermore, the condition 'dead' is – in contrast to the condition 'loser cow' – well defined and information regarding dead cows are available from the Danish Cattle Database. It was therefore decided to include an investigation of mortality among Danish dairy cows as the first part of the project.

The objectives of the present project were:

- to investigate mortality among Danish dairy cows and the risk factors for cow mortality
- to develop a definition of a loser cow based on a clinical examination of the individual cow
- to evaluate the consequences of the loser cow state on milk production, mortality etc.
- to estimate the occurrence (prevalence) of loser cows in large, loose housed, Danish dairy cattle herds
- to investigate major risk factors for the loser cow state
- to discuss strategies for the prevention and handling of loser cows.

The project was divided into four parts.

- *1. Investigations regarding mortality among Danish dairy cows.* Data from the Danish Cattle Database was used to evaluate the mortality among Danish dairy cows during the years 1990 to 2001. These investigations were supplemented by a questionnaire survey among Danish dairy farmers with the objective to investigate the development in the proportion of euthanised cows over time and the primary reasons for death or euthanasia (**paper I**). Finally, herd level risk factors for dairy cow mortality in Danish dairy cattle herds were investigated (**paper II**).
- *2. Definition of the condition loser cow.* This definition was sought by the development of a clinical scoring system. The clinical scoring system was evaluated regarding intra- and inter-observer agreement (**paper III**) and the relationship between the scores of individual cows and the consequences (on mortality, milk yield, morbidity, cullings and workload for the farmer) was evaluated (**paper IV**).
- *3. Evaluation of risk factors for loser cows.* A prospective observational study was conducted in 39 large, loose housed, Danish commercial dairy herds in the period September 2003 to October 2004. Each herd was visited three times with approximately 120 days between each visit. During each visit, all cows in the herd were examined using the clinical scoring system from Part 2. Cows were then classified as loser cows or non loser cows based on the definition from Part 2. The prevalence of loser cows was calculated and the effect of season on the prevalence of loser cows was evaluated (**paper IV**). The clinical examinations were supplemented with a description of the physical characteristics of each farm, management practices etc. recorded by a research technician from Research Centre Foulum and information about the herd and the cows from the Danish Cattle Database. Additionally, the farmer recorded workload and reasons for culling every time a cow left the herd. Herd level and cow level risk factors for loser cows were evaluated based on this information (**paper V**).
- *4. Discussion of strategies for the prevention of loser cows and handling of loser cows.* Based on the evaluation of risk factors for loser cows, strategies for the prevention and handling of loser cows were discussed.

2. Background

2.1 Mortality among dairy cows – an overview over the literature

Mortality among dairy cows constitutes a problem both in terms of financial losses (value of dead cows, decreased production and extra labour) and compromised animal welfare (suffering before death or euthanasia). A rise in the mortality among a group of cows can indicate sub-optimal health and welfare. Nevertheless, surprisingly few studies focusing on mortality among dairy cows exist (Harris, 1989; Gardner et al., 1990; Faye and Perochon, 1995; Menzies et al., 1995; Stevenson and Lean, 1998; Nørgaard et al., 1999).

2.1.1 Measures of mortality

The results from a number of studies on dairy cow mortality are summarised in Table 2.1. Direct comparisons of the mortalities found in different studies are difficult. Mortality can be calculated as mortality rate (e.g. per cow year) or mortality risk (e.g. per lactation). In some of the studies presented in Table 2.1, the exact measure was not specified.

2.1.2 Distribution of deaths in relation to time after calving

Milian-Suazo et al. (1988), Faye and Perochon (1995), Menzies et al. (1995) and Stevenson and Lean (1998) all found a high proportion of deaths during the first 15 or 30 days of the lactation.

2.1.3 Effect of age/parity

Faye and Perochon (1995) found a higher mortality among older cows. In contrast to this, Harris (1989) found no significant difference in mortality among cows of different ages.

2.1.4 Causes of death

Faye and Perochon (1995) found the major causes of death to be ‘other reasons’ (20 % of deaths), metabolic disorders (18 %), calving-related disorders (12 %) and accidents (8%) (in 33 % of all deaths, the reason was unknown). Menzies et al. (1995) found the major causes of death to be calving-related disorders (31 % of deaths), mastitis (25 %), other reasons (15 %), digestive disorders (13 %) and locomotor disorders (11 %). Milian-Suazo et al. (1988) found the major causes of death to be udder disorders (22 % of deaths) and other diseases (primarily metabolic disorders) (65 % of deaths). Esslemont and Kossaibati (1997) found the major causes of death to be Bovine Spongiforme Encephalopathi (BSE) (12 % of deaths), mastitis (9 %), other non-infectious disorders (8 %), metabolic disorders (8 %) and accidents (7 %). In 46 % of all deaths in that study, the reason was unknown.

2.1.5 Euthanasia

Results on the proportion of euthanised dairy cows (in relation to cows dying unassisted) has not been published.

Table 2.1. Summary of 10 studies on dairy cow mortality.

Study	Mortality	Country	Year of study	Number of cows/lactations and herds included
Nørgaard et al. (1999)	Crude death rate 3 – 4 %	Denmark	1974-1993	Calculated on the basis of data from incineration plants and annual counts of the Danish cattle population
Harris (1989)	1.09 – 1.40 % of cows depending on age	New Zealand	1985-1986	66,663 cows from 384 herds
Karuppanan et al. (1997)	Annual mortality rate 0.012 – 0.042 depending on herd	USA	1987-1992	19,482 cows from 9 herds
Milian-Suazo et al. (1989)	1.2 % of lactations studied ended in death	USA	1981-1985	7,763 lactations from 34 herds
Esslemont and Kossaibati (1997)	Annual mortality rate 0.016	England	1990-1992	26,644 lactations from 50 herds
Faye and Perochon (1995)	Annual mortality rate 0.0096	France	1986-1990	4,129 cows (8,945 lactations) from 47 herds
Stevenson and Lean (1998)	4.3 % of cows in the study	Australia	1992-1994	1,642 cows from 8 herds
Gartner (1983)	Mortality risk 1.1 – 1.8 %	England, Wales, Scotland	1973-1976	11,352 lactations from 18 herds
Menzies et al. (1995)	Annual mortality rate 0.0155	North Ireland	1992	1,069 herds
Gardner et al. (1990)	Mortality rate 2.0 per 100 cow years at risk	USA	1986-1987	16,039 cows from 43 herds

2.1.6 Herd level risk factors for dairy cow mortality

The possible relationship between herd factors and cow mortality has been investigated only sporadically. Batra et al. (1971) and Smith et al. (2000) investigated herd size and milk production level as potential risk factors for cow mortality. Smith et al. (2000) found increasing mortality rates with increasing herd size among dairy cattle herds in the eastern part of the United States. However, no significant relation between percentage of dead cows and herd size was found in Canadian herds

(Batra et al., 1971). Smith et al. (2000) found a decrease in mortality rate with increasing milk production level among dairy cattle herds in the eastern part of the United States, whereas Batra and others (1971) found no significant relation between percentage of dead cows and herd level milk production in Canada. Bascom and Young (1998) found no significant relation between milk production and death as a culling reason.

2.2 Loser cows – a new concept

The concept of loser cows has been introduced by the present project and the word loser cow has been 'invented' during the first part of the project. Therefore, obviously no previous literature dealing with loser cows exist. However, a number of studies have used some of the same methodologies (evaluation of multiple clinical signs in individual cows – often combined with recordings of management and/or physical characteristics of stables etc.). A brief overview over some of these studies will be given here with the focus being on the methods used.

Regula et al. (2004) compared health and welfare of dairy cows in three different husbandry systems. A total of 134 Swiss dairy herds were visited two or three times. All the cows in the herd or a sample of the cows (in larger herds) were examined for lameness, skin alterations at the hock joints, scars or injuries at the teats, skin injuries at other locations, body condition score, cleanliness and general health status. Additionally, farm characteristics, management practices and disease treatments were recorded.

Klaas et al. (2003) evaluated the impact of lameness on welfare in Danish dairy herds with automatic milking systems. Eight herds were visited four times. During each visit 40-50 cows were randomly assigned for clinical examination of body condition, cleanliness, skin lesions, parasitic infestations, claw length, disorders of claws and legs, lameness, pressure lesions, disorders of udder and teats and overall condition.

Rodenburg et al. (1994) evaluated the use of rubber mats and mattresses, respectively, in a study in 18 Holstein herds from Western Ontario. All cows in the herds were given a score for cleanliness and hock injuries. Additionally, they recorded management parameters (e.g. use of bedding) and physical characteristics of the barns and cubicles.

Chaplin et al. (2000) compared the relative merits of mats and mattresses in terms of cow comfort and production over a whole housing period (28 weeks). They studied two groups of 29 cows each from two research herds in Scotland. One group was housed on rubber mats and one group on mattresses. Every two weeks all cows were weighed and scored for body condition, lameness, dirtiness and hock and knee injuries. Additionally, some of the cows were subjected to 24 hour behavioural observations 7 times during the housing period.

Busato et al. (2000) evaluated the frequency of traumatic cow injuries in relation to housing system in 152 organic dairy farms in Switzerland. Every farm was visited once and all cows were scored for claw, skin and joint lesions and body condition. The body weight of the cows were estimated by tape measure. Additionally, information about management was collected using a combination of a questionnaire and measurements in the barn.

Blom et al. (1983) studied the effect of different housing conditions on the occurrence of traumatic injuries to dairy cows. Thirty Danish dairy herds were studied over a period of 6 years. All cows were scored three times a year regarding traumatic injuries to the limbs, neck and body. Additionally, information regarding disease treatments and housing system was recorded.

Enevoldsen et al. (1994) studied the occurrence of physical injuries to the body and thighs of dairy cows and the association between these injuries and a number of cow characteristics. All cows from 18 Danish dairy herds were examined by a veterinarian three times a year. Scores were assigned for contusions and/or wounds on the costal arch, thigh, hip and ischial arches. Body weight of the cows was recorded in the spring and fall and at culling. Detailed recordings of claw health were made at claw trimming (twice during each lactation). Additionally, all disease treatments requiring injections and/or the use of antibiotics were recorded.

Whay et al. (2003) assessed the welfare of dairy cattle using animal-based measurements. The study included 53 English dairy herds. Each herd was visited once. Twenty percent of the cows in each herd were selected for detailed observations. Dirtiness of the hind limbs, udder and flank, condition of the coat (baldness, dullness and hairness) and state of the rumen (bloated or hollow) were recorded. Signs of injury or trauma such as hair loss, swelling or ulceration were recorded, with special emphasis given to the hocks, tuber coxae, tuber ischium, and the skin covering the ribs. The claws were observed for evidence of infection or injury, overgrowth, poor conformation or abnormal angle of the pastern. The overall appearance of the cows were assessed and they were scored for lameness. Additionally, information about production and diseases were collected. Huxley et al. (2004) have used the methods described by Whay et al. (2003) in a study including 15 organic dairy herds in England.

Haskell et al. (2003) evaluated the effect of management and housing type on behaviour and welfare of dairy cows in British dairy herds. A sample of the cows were observed and locomotion score, body condition score, cleanliness score and the incidence of physical injuries were recorded. Additionally, they recorded behaviour of the cows, quality of 'stockpersonship' and a number of measurements regarding the physical characteristics of stables etc.

Vokey et al. (2001) evaluated the effect of alley and stall surfaces on claw and leg health in a university dairy herd. They scored hind claws and hocks of 120 cows for lesions. The cows were scored for lameness four times. The presence of digital dermatitis and interdigital dermatitis was recorded and rates of claw growth and wear were calculated.

Winckler et al. (2003) discussed the selection of parameters for on-farm welfare assessment in cattle and buffalo with the aim of proposing a scientifically accepted assessment tool in the framework of a single farm visit. Their criteria for selection were validity, reliability and feasibility. They concluded that lameness scoring, physical injuries, body condition score and cleanliness were among the measures that fulfil these requirements.

3. Methodological considerations

Three statisticians went hunting. They spotted a moose.
The first statistician shot, but he hit one meter left of the animal.
The second statistician then shot, but he hit one meter right of the animal.
The third statistician did not shoot, but jumped up with joy and shouted
'we got it, we got it, we got it'.

Many of the statistical methods used during this Ph.D.-project are 'standard statistical methods'. They have been described in the relevant papers (Chapters 5, 6, 7, 8 and 9) and will not receive further attention here. Instead, the present chapter deals with some more fundamental methodological considerations concerning study design, sampling, disease measures etc.

3.1 General study design

We studied loser cows in Danish dairy herds with loose-housing systems using a prospective, observational study. A repeated, cross-sectional study design was used. All study herds were visited three times with an interval of approximately 120 days. During each visit, all cows in the herds were examined (cluster sampling). This way, some cows were examined 3 times, some cows were examined twice and some only once. This repeated, cross-sectional study design made it possible to evaluate the prevalence of loser cows in Danish dairy herds and evaluate the effect of season on the prevalence of loser cows. Additionally, it will be possible to evaluate whether the loser cow state should be regarded as reversible or irreversible as a large proportion of the cows in the study has been examined two or three times.

As an alternative, the number of study herds could have been three times higher and the individual herd only visited once. This situation would have meant a larger possibility for the identification of statistically significant risk factors for loser cows. However, the evaluation of the consequences of the loser cow state would have been difficult for the cows examined during the last half of the study period. The follow-up period for these cows would have been relatively short (a few months). This was the reason behind our decision to only evaluate the consequences of the loser cow state for cows examined during the first round of visits to the herds. These cow all had a follow-up period of no less than 8 months.

3.2 Sample size considerations

Before the start of the study the required sample sizes were estimated. The objective of these calculations was to estimate an appropriate sample size, which, on the one hand, would give results of an acceptable precision and, on the other hand, would not waste resources by being too large (Woodward, 1999). The main results of these calculations are presented below.

3.2.1 Sample size to estimate the proportion of loser cows

We evaluated the sample size necessary for estimating the proportion (prevalence) of loser cows. The calculations were based on the formula:

$$n = \frac{Z^2_{1-\alpha/2} \quad p\,(1-p)}{L^2} \qquad \text{(Toft et al., 2004)}$$

where n is the required sample size,

$Z_{1-\alpha/2}$ is the value of the standard normal distribution corresponding to a two-sided confidence level of $1-\alpha/2$ (= 1.96 for a 95 % confidence level)

p is an estimation of the proportion of interest and

L is the maximum allowable error.

Note that the formula requires a guess of the size of the proportion being estimated. In the absence of such a guess p=0.5 way be used, as the sample size (n) is maximised when p=0.5. Thus, setting p at 0.5 will give a sample size that is always sufficiently large.

Setting p at 0.5, $Z_{1-\alpha/2}$ at 1.96 and L at 0.01 we get:

$$n = \frac{1.96^2 * 0.5*(1-0.5)}{0.01^2} = 9604.$$

A small pilot study in 4 herds indicated that the proportion of loser cows would be approximately 0.05. Using this value for p we get:

$$n = \frac{1.96^2 * 0.05*(1-0.05)}{0.01^2} = 1825.$$

As the proportion of loser cows might turn out to be larger than in the pilot study, we concluded that approximately 4,000 cows in each of the three rounds of herd visits (corresponding to an expected proportion of loser cows of no more than approximately 0.12) was an acceptable sample size for the evaluation of the prevalence of loser cows.

3.2.2 Sample size for the evaluation of risk factors

The sample size for the evaluation of risk factors at the cow level was calculated as described by Hsieh (1989). The confidence level was set at 95 % and the power at 80 %. The overall expected proportion of loser cows was set at 0.05. To be able to detect an odds ratio (OR) of 2.0 we then needed a sample size of 285 cows using univariate logistic regression (sample size with OR=1.2: 4086 cows; sample size with OR=1.5: 823 cows; sample size with OR=3.0: 139 cows). Using multiple logistic regression the sample size should be divided by the factor $1-\rho^2$, where ρ denotes the multiple correlation coefficient relating the specific covariate of interest to the remaining covariates. Assuming $\rho=0.2$, the required sample size increases with approximately 4.2 %. Increasing the power to 90 % will increase the required sample size by approximately 35 %. A sample size of approximately 4,000 cows in each of the three rounds of herd visits was considered a sufficiently large sample size in relation to the evaluation of risk factors at the cow level.

Calculation of the number of herds to be included in the study can be done as described for the cow level above. However, due to considerations regarding time and costs it was decided that it was only possible to include 40 herds in the study. These 40 herds would have a minimum total number of cows of 4,000 as the minimum herd size for herds included in the study was set at 100 cows per herd. Thus, 40 herds would have a sufficiently large number of cows for the evaluation of both the prevalence of loser cows and cow level risk factors.

3.3 Selection of herds

The selection of the herds for the study is discussed in details in Chapter 8. Only a few fundamental issues regarding the selection procedure will be addressed here. The herds were selected randomly among herds that met the following criteria: Loose-housing system, more than 100 cows during the period 1st October 2001 to 30th September 2002, primarily Danish Holstein (more than 95 % of the cow days in the herd constituted by Danish Holstein), herd participating in milk recording (member of a Milk Control Association) and cows being conformation scored by breeding inspectors from a cattle breeding organisation. Additionally, only herds in a distance of less than approximately 150 km from the Danish Institute of Agricultural Sciences, Research Centre Foulum, and herds with an acceptable level of disease recordings prior to the start of the study were considered, when the herds were sampled. Among the herds that met these inclusion criteria 40 herds with a co-operative farmer were selected randomly. One herd was not able to keep acceptable records regarding culling of cows. At the same time this herd was the only herd where we were not able to examine all the cows. Approximately one third of the cows were breed by a bull. This made examination of these cows impossible. This herd was therefore excluded from the study.

The inclusion of only large herds with loose-housing systems was based on the assumption that herds with these characteristics will be ‘the herd of the future’ in Danish dairy production (Barrett, 2004). A larger number of herds with fewer cows in each herd would also have meant more time spend on transportation between herds. Additionally, we would not have been able to evaluate lameness easily in cows housed in tie stall barns.

The geographical restrictions regarding the herds that were invited to participate in the study were aimed at reducing the time used for the observer travelling between herds (convenience sampling). The location of the herds included in the study is shown in Figure 3.1. The area from where the herds were selected houses approximately 2/3 of the Danish dairy cattle population (Anon., 2004). We have no reason to believe that dairy herds in this part of Denmark differ from other Danish dairy herds in any systematic way.

The herds in the study were all members of a milk control association, their cows were conformation scored, disease recordings were acceptable and the farmers were willing to participate in the project even though this gave them extra paperwork (registration of workload, culling mode and reason when a cow was culled). The farmers were not paid for their participation in the project. By selecting herds with these characteristics we expected to get much information of a high quality. The disadvantage of this selection procedure was that the selected herds might not be considered as a representative sample of the population of Danish dairy herds. Some might claim that these farmers were more enthusiastic, took a greater interest in their cows and were more willing to keep good records compared to ‘an average farmer’. However, we found that some degree of selection was needed to ensure adequate information of an acceptable quality. The farmers participating in the study might be 'better' farmers than the average Danish dairy farmer. If so, one might expect that the problems with loser cows will be even greater in 'the average Danish dairy herd' compared to the herds participating in this study. In general, we still believe that the herds selected for this study do not differ from other Danish dairy herds in any systematic way. We therefore believe that the conclusions from this study are valid for all large Danish dairy herds with loose-housing systems.

Figure 3.1. Location of the herds participating in a Danish study of loser cows.
Herd Danish Institute of Agricultural Sciences, Research Centre Foulum

3.4 Loser cow score

Basically, disease can be diagnosed using one or more of four criteria (Thrusfield, 1995):

1. Clinical signs and symptoms
2. Detection of specific agents
3. Reactions to diagnostic tests
4. Identification of lesions

The diagnosis of a particular disease depends on *observations* of clinical signs, presence of specific agents or lesions and/or test results and a subsequent *interpretation* of these observations. As an example, a veterinarian that *observes* the clinical signs anorexia, dry faeces and a sudden decrease in milk production in a cow combined with a test that indicates elevated levels of ketone bodies in milk or urine, will *interpret* these observations and *conclude* that the correct diagnosis is ketosis.

In human medicine scores have been used extensively to describe (complex) clinical phenomena. Several hundred scores (often called scales, ratings, systems, indexes or criteria instead) have been developed and used (Feinstein, 1987; McDowell and Newell, 1987). Hensyl (1990) defines a 'score' as: 'An evaluation, usually expressed numerically, of status, achievement, or condition in a given set of circumstances'. A score can cite the absence, presence, or degree of magnitude for relatively simple clinical entities, such as pain, discomfort or distress. However, the name score is most often used to describe variables that are formed as a mixture of two or more underlying variables, which are called the components of the score. These components are often recorded as arbitrary non-dimensional categories (such as 0, 1, 2). The goal of most scores is to combine a (large) number of variables into a single output expression (the final score) that will offer a rating for a complex clinical condition (Feinstein, 1987). Composite scores have been shown to possess greater overall reliability and validity than subjective methods (Scott et al., 2001).

One of the most widely used and well-known scores is the Apgar score. The Apgar score was developed by Dr. Virginia Apgar in 1952. The purpose of the Apgar score was to provide medical science with a uniform method of observation and evaluation of a newborn infant's need for resuscitation immediately after delivery. Later, the Apgar score has been used for many other purposes including the prediction of neonatal survival. The Apgar score is formed from five component variables, which refer to heart rate, respiratory rate, colour, muscle tone and reflex response to nasal catheter. Each of the component variables has its own rating scale, containing the three categories 0, 1 and 2, and the Apgar score is formed as the sum of these five ratings. From 1952 to the present day hundreds of millions infants throughout the world have received an Apgar score one and five minutes after delivery (Apgar, 1953; Apgar and James, 1962; Feinstein, 1987; Sellers, 2005).

3.4.1 Selection of clinical signs and scores

The choice of the clinical signs included in the clinical protocol and the loser cow score was based on a practical consideration. Basically, all relevant clinical signs that could be assessed from a distance of 1-2 meters without any fixation of the cow were included. Dry udder quarters, asymmetry of the udder and amputated teats were recorded during the herd visits for use in another project, but these udder characteristics were considered of minor relevance in relation to loser cows and were therefore not included in the loser cow score.

The loser cow score is presented in detail in Chapter 4 (section 4.4.1), Chapter 8 and in Appendix 1. The choice of scores for the individual clinical signs (component variables) has been carefully considered. The arguments for these choices will be presented subsequently.

Lameness: A large number of scoring systems for the evaluation of lameness in cattle exists. Whay (2002) has reviewed many of them. They vary in complexity from simple ‘lame’ or ‘not lame’ systems to relatively complicated systems with 9 different scores for lameness (Manson and Leaver, 1988). We wanted a system that was not too simple nor too complicated. A simple system may oversimplify the clinical reality and result in a loss of information and a system with too many scores may be difficult to use in practice (Feinstein, 1990; Streiner and Norman, 2003). Additionally, we wanted a system that had been evaluated in relation to reliability (inter- and intra-observer agreement). Based on these requirements we chose the lameness scoring system described by Sprecher et al. (1997). They have included the shape of the cow’s spine in the lameness scoring system. This way it should be easier to identify mildly lame cows. The scoring system has been widely used by others (their article has been cited 29 times by July 2005). Winckler and Willen (2001) have evaluated a slightly modified version of the scoring system. They concluded that it was reasonably quick and easy to use. Locomotion scores in individual cows were significantly correlated with lesions found at claw trimming and the inter-observer agreement was high.

Body condition score: Scores for body condition were modified after Ferguson et al. (1994). This body condition scoring system was based partly on the work of Edmonson et al. (1989). The system has been used extensively (their article has been cited 74 times by July 2005) and several authors have evaluated the system (e.g. Domeco et al., 1995; Schwager-Suter et al., 2000). Based on a number of different reasons we chose to modify the body condition scoring system. Cows were classified according to body condition scores as shown in Table 3.1.

Table 3.1. Classification of cows in relation to body condition score in a study of loser cows in Danish dairy herds.

Body condition score (BCS)	Classification
BCS>=4	Fat
2.25<=BCS<=3.75	Normal
1.5<=BCS<=2	Thin
BCS<=1.25	Emaciated

The reasons for this simplification of the body condition score were:

- Only extreme deviations from the ideal body condition score are assumed to be relevant for the health and welfare of the cows (Winckler et al., 2003; Regula et al., 2004). Such deviations would be recorded using the modified system.
- A small pilot study has shown that the amount of time used for observation of each cow will approximately double (from 1 minute to 2 minutes per cow) if cows were to be body condition scored using the original system instead of the modified system. This extra time spent on observations would have meant an extra workload of approximately 250 hours during the herd visits. It was estimated that the time used for herd visits could not be increased within the time frame of the project. Therefore, the only alternative was a reduction of the number of herds (or the number of visits to each herd) included in the study or a reduction of other parts of the clinical protocol. Neither of these options were considered acceptable.
- Even if we had recorded body condition scores on the original scale, we could not have used the information recorded for the generation of body condition profiles in relation to stage of

lactation as the cows in the study were not examined at fixed times in relation to calving or drying-off. This fact limits the potential use of body condition scores.

Hock lesions: A large number of authors have proposed scores for hock lesions (e.g. Gustafson, 1993; Rodenburg et al., 1994; Busato et al., 2000; Chaplin et al., 2000; Weary and Taszkun, 2000; Wechsler et al., 2000; Vokey et al., 2001; Livesey et al., 2002; Regula et al., 2004). However, no single scoring system has been widely used or accepted. A new scoring system seems to have been developed for each new study. We evaluated the existing scoring systems. Some of them were found too simple (e.g. Livesey et al. (2002), who classified hock lesions as 1) absent, 2) hair loss only or 3) all other damage), and some were found too elaborate (e.g. Vokey et al. (2001), who used a system where hock lesions were scored on a scale from 0 to 8). In general, many of the authors focussed on the presence of hair loss and wounds. In many cases, the presence or absence of swellings (hyperkeratosis, fluid filled bursae, abscesses etc.) were not included in the scores. We therefore decided to develop a new scoring system for this study. The system was to be not too simple and not too elaborate and both hair loss, wounds and swellings were to be included. The resulting scores are presented in Appendix 1. The idea of only recording the worst lesion present has also been used by e.g. Rodenburg et al. (1994) and Regula et al. (2004).

Other cutaneous lesions: A number of authors have proposed scores for other cutaneous lesions (e.g. Busato et al., 2000; Chaplin et al., 2000; Klaas et al., 2003; Regula et al., 2004). As with scores for hock lesions no single scoring system has been widely used or accepted. We evaluated the existing scoring systems, but as with hock lesions we found none of the existing systems suitable for our use and developed our own scoring system, which is presented in Appendix 1. The basic ideas behind the development are the same as described above for the scores for hock lesions.

Vaginal discharge: Vaginal discharge was scored on a simple dichotomous scale (present/absent). To increase the likelihood of observing cows with vaginal discharge (i.e. increase the sensitivity) all cows with vaginal discharge seen from the vagina as well as on the tail and/or perineum were recorded as having vaginal discharge.

Skin condition: Several authors have published scoring systems for skin condition (often designated cleanliness) (e.g. Scott and Kelly, 1989; Bergsten and Pettersson, 1992; Chaplin et al., 2000; Schreiner and Ruegg, 2002; Bowell et al., 2003; De Rosa et al., 2003, Whay et al., 2003). In general, most of these scoring systems were designed for an evaluation of the effect of cleanliness on e.g. hoof health, milk quality or intramammary infections (Bergsten and Pettersson, 1992; Schreiner and Ruegg, 2002; Schreiner and Ruegg, 2003) or an evaluation of the negative effects of a dirty coat on the well-being of the cow (itching, reduced capacity of thermoregulation, etc.) (Winckler et al., 2003). However, in our study the main purpose of scoring the skin condition was to detect cows that were not able to keep themselves clean (self-grooming). The cleanliness of cows depends to a large extend on management factors (Scott and Kelly, 1989). Nevertheless, a lack of grooming in cows and the resulting dull and dusty coat may be a sign indicating decreased general health or thriftiness (Albright and Arave, 1997; Hulsen, 2005). We therefore chose to develop a score for skin condition that focussed on detecting cows that were not able to keep themselves clean.

General condition: Evaluation of the general condition has been included in the studies of e.g. Klaas et al. (2003), Whay et al. (2003), and Regula et al. (2004). However, none of these authors have presented any descriptions of how to score the general condition. Therefore, we developed our own score for the general condition of the cows.

3.4.2 Weights for the loser cow score

The scores for the individual clinical signs were converted into a loser cow score. A scaling model is a technique that allows weights to be assigned to the components of a score. There are two main types of scaling models: direct estimation techniques and indirect techniques. Direct estimation techniques assign weights to the individual component scores subjectively based on the perceived importance of each score (Feinstein, 1987; McDowell and Newell, 1987; Scott et al., 2001; Dohoo et al., 2003; Scott et al., 2003; Streiner and Norman, 2003). Using indirect techniques the weight for each component score is derived from experimental observations. Indirect techniques is used to 'calculate' a single number that represents the overall level of some concept (e.g. the level of animal welfare in a group of dairy calves) (McDowell and Newell, 1987; Scott et al., 2001; Scott et al., 2003). Indirect techniques is based on a number of judges comparing the association of a number of items to an attribute of interest (e.g. welfare). Each judge compares pairs of items and identifies which item is associated with the highest degree of the attribute (e.g. is chronic pneumonia or the lack of contact with other calves associated with the highest degree of welfare in dairy calves). These comparisons allow the items to be ordered relative to each other and weights for each item can be estimated by transforming the observed proportions (Scott et al., 2001; Trochim, 2002).

Scott et al. (2001) recommended the use of indirect techniques to assign weights to the items included in a score reflecting the level of animal welfare. However, indirect techniques is suitable only in specific situations and was not found suitable in the present setting as it is not designed for situations where a single item (e.g. hock lesions) is measured on an ordinal scale. Indirect techniques normally only is used in situations where individual items are measured on a dichotomous scale (agree/disagree, present/absent) (Scott et al., 2001; Trochim, 2002). Wright and Feinstein (1992) discussed the use of direct and indirect techniques and stated that indirect techniques for a number of technical reasons normally are not a good strategy when it comes to clinical situations. McDowell and Newell (1987) stated that both direct and indirect techniques may be useful and that the choice between different techniques may be regarded as a choice between theoretical sophistication and simplicity.

A direct estimation technique was chosen for the assignment of weights to each of the clinical scores. The conversion of the scores for the individual clinical signs into the loser cow score was based on an assessment of the relative importance of the deviation from the normal condition (represented by a perfectly normal, healthy cow) for each of the clinical signs observed. This assessment was made after consulting a group of experts in veterinary and animal science. The deviation from the normal condition for each clinical sign were weighted both in relation to the degree of deviation from the normal condition regarding that particular sign and in relation to the other clinical signs. The normal condition and deviations from the normal condition that were considered of no or only minimal clinical importance were assigned the value '0'. To recognize the greater clinical importance of higher scores we used a geometrically progressive scale (powers of 2: 2^0, 2^1, 2^2 and 2^3). This method has previously been described by Greenough and Vermunt (1991), Leonard et al. (1996), Offer et al. (1997) and Winckler and Willen (2001). The conversion into points for the loser cow score is shown in Table 4.3. The loser cow score was defined as the sum of the points for each of the seven clinical signs. In this way each cow was assigned a loser cow score ranging from 0 to a theoretical maximum of 32.

3.4.3 'Measuring' loser cows on a discrete or a dichotomous scale?

All cows in the study were assigned a loser cow score. Additionally, we wanted to classify cows as loser cows and non loser cows, respectively. We classified cows with a loser cow score of 8 or more as loser cows. The choice of 8 as the threshold between loser cows and non loser cows is addressed in detail in Chapter 8. The farmers that 'inspired' us to start this project generally looked at the loser cow state as a dichotomous variable: loser cow or non loser cow. This was the main reason for the 'transformation' from a quantitative (discrete) scale (the loser cow score) to a dichotomous scale (loser cow or non loser cow). Using a dichotomous scale might cause a loss of information, but facilitates communication and understanding (Streiner and Norman, 2003). Both scales might be useful in the future, depending on the specific purpose.

The literature contains numerous examples of diseases that are in fact measured on a continuous or a discrete scale, but which are normally treated as being dichotomous: healthy or diseased. Lameness in cattle might be recorded on a discrete scale (lameness score) and transformed into the categories 'lame' and 'non lame' (e.g. Clarkson et al., 1996; Hirst et al., 2002; O'Callaghan et al., 2003; Garbino et al., 2004). The concentration of ketone bodies in milk, urine or blood might be measured on a continuous scale and then transformed into the categories '(subclinical) ketosis' and 'healthy' (e.g. Gustafsson and Emanuelson, 1996; Duffield et al., 1998; Green et al., 1999; Enjalbert et al., 2001). Blood pressure in humans is measured on a continuous scale (mm Hg), but still individuals are classified as either 'normal' or 'suffering from hypertension' (Dolgin et al. 1994). The concentration of cholesterol in the blood in humans is measured on a continuous scale, but still individuals are classified as 'normal' or 'suffering from hypercholesterolemia' (Cox and García-Palmieri, 1990). Blood glucose concentration is measured on a continuous scale in cats and dogs, but still individual animals are classified as 'normal' or 'diabetic' (Nelson, 1989).

In all these cases, the 'correct' threshold between healthy and diseased is somewhat arbitrary. The use of a systolic blood pressure of 140 mm Hg and a diastolic blood pressure of 90 mm Hg as the threshold for classifying a human as either 'normal' or 'suffering from hypertension' (Dolgin et al., 1994) or the use of a threshold of 0.4 mmol acetone per litre milk between 'normal' and 'hyperketonaemic' cows (Gustafsson and Emanuelson, 1996) might be disputed.

3.4.4 Simple loser cow score

The 'original' clinical protocol included 7 clinical signs. The prevalence of deviations from the normal condition for these clinical signs were expected to vary from sign to sign. Clinical signs where deviations from the normal condition have low prevalences add little information at the cost of relatively much extra work (Streiner and Norman, 2003). To make the loser cow score more easy to use for future research and use in practice, we wanted to evaluate a simplified loser cow score, where clinical signs with a low prevalence were omitted. Clinical signs with a prevalence of deviations from the normal condition below 5 % were omitted in a 'simple loser cow score'. Such principles of omission have been described by Streiner and Norman (2003).

3.4.5 Relation to lameness

We wanted to evaluate the relation between the new 'diagnosis' loser cow and lameness. Lameness was one of the clinical signs included in the clinical protocol. The maximum number of points that a cow could attain for lameness was 8 (given to a severely lame cow). A cow may therefore become classified as a loser cow solely on the basis of lameness. We therefore wanted to evaluate whether a loser cow is in fact just another way of describing a lame cow. To do so, we evaluated the consequences of being a lame cow in the same way as we evaluated the consequences of being a loser cow. Furthermore, we calculated a loser cow score where lameness was not included. This score was identical to the loser cow score except that lameness was not included.

3.5 Evaluation of the clinical protocol

During the present study the clinical protocol has been used by one observer only. Hopefully, the clinical protocol is going to be used to assign loser cow scores in both research and clinical practice in the future. In these settings a larger number of observers is expected to use the clinical protocol. Therefore, it is desirable to evaluate the ability to generalize the results. Feinstein (1987) states that 'just as a cook needs a recipe to prepare something new or unfamiliar, a person who is going to use an index must be given a suitable set of directions. If variations occur in the product that emerges when the recipe is used by different cooks, the differences might be due to the personal culinary vicissitudes of the cooks, but another source of inconsistency may be inadequacies in the recipe itself'. To evaluate the 'quality of our recipe', we have evaluated the clinical protocol among potential future users regarding intra- and inter-observer agreement. A thorough description of this evaluation is given in Chapter 7.

3.5.1 Choice of method

Cohen's kappa has been widely used to assess observer agreement (e.g. Brothwell et al., 2003; Molander et al., 2003; Venhola et al., 2003; Petersen et al., 2004; Stavem et al., 2004). However, the use of kappa has several disadvantages. Kappa depends not only on the agreement between the observers, but is also affected by the distribution of observations within the m x n contingency matrix (the prevalence of the clinical trait observed and the presence of bias between observers) (Byrt et al., 1993; Lantz and Nebenzahl, 1996; Dohoo et al., 2003). Additionally, kappa allows only simultaneous comparison of two observers (Woodward, 1999). We therefore chose to use a hierarchical Bayesian threshold model to evaluate inter-observer agreement (Baadsgaard and Jørgensen, 2003; Baadsgaard and Jørgensen, 2005). This model allowed us to calculate sensitivity and specificity for the observers. Intra-observer agreement was evaluated using the kappa-coefficient. We were not able to use the Bayesian threshold model for this subset of the data because the number of observations was too small.

3.6 Data from the Danish Cattle Database

The Danish Cattle Database (DCD) is managed by the Danish Cattle Federation. The information in DCD is coordinated with information from the Central Farm Animal Register (in Danish: CHR-register). The Central Farm Animal Register is managed by the Ministry of Food, Agriculture and Fisheries in collaboration with the cattle industry. It contains information on all agricultural holdings with farm animals. Every cattle must be registered with information on date of birth, breed, sex and the dam. Additionally, information on calvings, movements and deaths must be reported (Houe et al., 2004). DCD contains registrations from farmers, dairies, slaughterhouses, veterinarians, cattle-breeding organisations and milk quality and veterinary laboratories. Recorded data include e.g. individual cattle pedigrees, their breeding values, meat-quality data, meat-inspection data, disease treatments, services, calvings, deaths, milk yield and composition (fat, protein, somatic cell count). In addition to registrations about individual cows, DCD also contains information about herds, such as size and location. Some information is reported on a voluntary basis, whereas the farmers are required by law to report other information to DCD/Central Farm

Animal Register (e.g. information about deaths, calvings and transfer between herds) (Houe et al., 2004).

Some information is registered in more than one way. Slaughter of a cow is e.g. registered both by the farmer and by the slaughterhouse, a dead cow is registered both by the farmer and by the incineration plant and transfer between two herds is registered both in the herd from where the cow leave and in the herd the cow enters.

3.6.1 Data quality, control and editing

Several authors have stressed the importance of data of a high quality (e.g. Dohoo et al., 2003; Houe et al., 2004). Generally, data from the Danish Cattle Database is considered of a high quality (Anon., 2003; Bundgaard, 2005). However, the quality of data regarding disease treatments has been questioned by some authors (Bartlett et al., 2001; Bennedsgaard et al., 2003). To ensure data of the highest possible quality we have performed control/verification of data whenever possible. This control was e.g. based on agreement between information registered in more than one way, evaluation of extreme values (outliers), invalid values, frequency distributions and scatterplots. In general, only very few erroneous recordings were found. When an erroneous recording was found, it was corrected, if possible, or deleted.

4. Main results – an overview

This chapter of the thesis gives an overview of the essential results of the project. For a more thorough presentation of the results, the reader is referred to Chapters 5, 6, 7, 8 and 9. In these chapters, the results are presented in a much more elaborate manner. Materials and methods are also described briefly in the present chapter where it was found necessary for the understanding of the results.

4.1 Mortality among Danish dairy cows

4.1.1 Data from the Danish Cattle Database

Data from the Danish Cattle Database were used to study the development in the mortality risk among Danish dairy cows from 1990 to 2001. Data from more than 7.2 million lactations were included in the study. Mortality risk (including both unassisted dead and euthanised cows) for the whole lactation and the subsequent dry period among Danish dairy cows from 1990 to 1999 is presented in Figure 4.1.

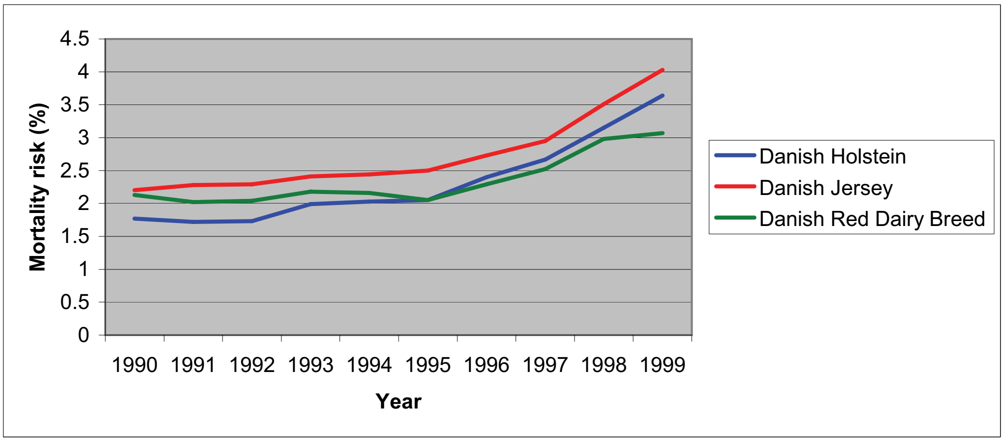

Figure 4.1. Breed-specific mortality among Danish dairy cows, 1990 – 1999. (With permission from Preventive Veterinary Medicine).

Mortality risk has increased for all dairy breeds and for all age groups during the years. The increase seems parallel for all parity groups, but the risk among older cows (parity 3 or older) is approximately twice that of the younger cows (Figure 4.2).

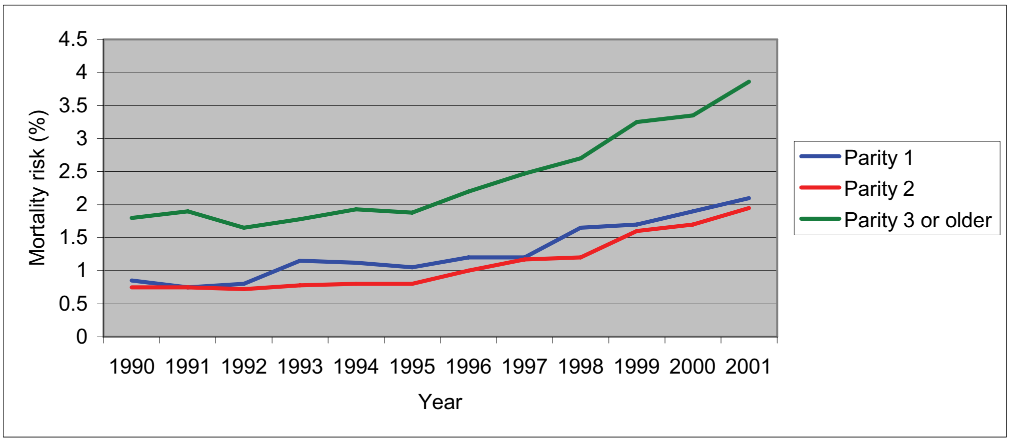

Figure 4.2. Parity-specific mortality among Danish Holstein cows during the first 100 days of the lactation, 1990 – 2001. (With permission from Preventive Veterinary Medicine).

Survival after calving for Danish Holstein is presented in Figure 4.3. Differences between all parities of Danish Holstein were highly significant (p<0.0001). Results for the other breeds are not shown, but were similar to the results shown for Danish Holstein.

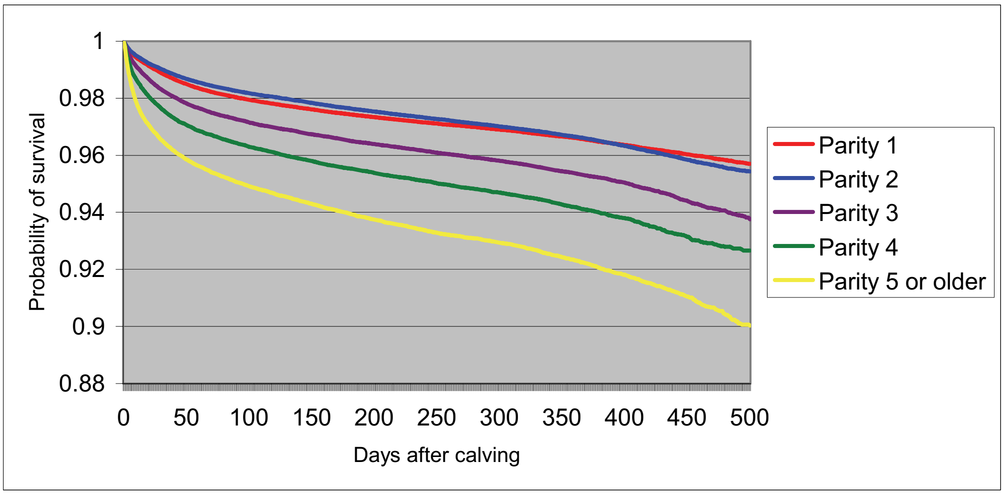

Figure 4.3 Parity-specific survival after calving for Danish Holstein cows for the years 2000 and 2001. (With permission from Preventive Veterinary Medicine).

A relatively large proportion of the deaths occurred during the start of the lactation. 30.5 % of the dead young (parity 1 and 2) Danish Holstein cows died during the first 30 days of the lactation compared to 41.1 % of the older cows. During the first 30 days of the lactation, the distribution of deaths was also uneven, with the highest mortality during the first few days after calving.

4.1.2 Questionnaire survey

We evaluated the proportion of euthanised dairy cows (in relation to cows dying unassisted) using a questionnaire survey. A total of 196 Danish dairy farmers were interviewed over the telephone. The farmers were selected randomly among farmers that had reported a dead cow to the Danish Cattle Database. Replies from the survey showed that 58 % of the dead dairy cows were euthanised. Furthermore, the replies indicated that the proportion of euthanised cows had increased. More than half of the farmers (55 %) stated that they euthanised relatively more cows in 2002 than five years earlier. The primary reasons for death or euthanasia as stated by the farmer are presented in Table 4.1.

Table 4.1. Primary reasons for unassisted death or euthanasia of dairy cows as stated by the farmer in a questionnaire survey. (With permission from Preventive Veterinary Medicine)

Primary reason	Unassisted dead cows (% of n=82)	Euthanised cows (% of n=114)
Accident	5	12
Calving disorder	10	7
Digestive disorder	17	11
Locomotor disorder	2	40
Metabolic disorder	15	8
Udder/teat disorder	11	8
Other	12	10
Unknown	28	4

4.2 Herd level risk factors for dairy cow mortality

Herd level risk factors affecting cow mortality in Danish dairy cattle herds were studied using data from 6,839 dairy herds and analysed using logistic regression. All Danish dairy herds that were milk recorded from the 1st October 2000 to 30th September 2001 were included in the study. The mean mortality risk at the herd level for the first 100 days of the lactation was 2.5 %. The distribution of the mortality risk at the herd level during the first 100 days of the lactation is shown in Figure 4.4.

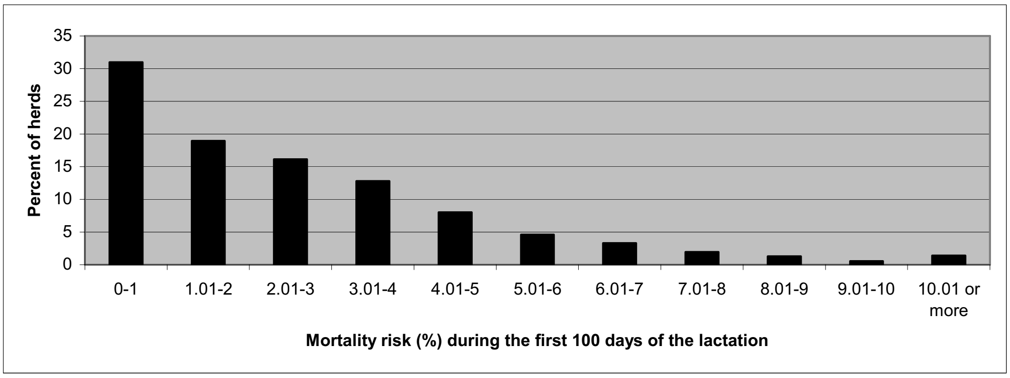

Figure 4.4. Distribution of mortality risk during the first 100 days of the lactation at the herd level in 6,839 Danish dairy herds.

The results of the logistic regression are summarised in Table 4.2. All explanatory variables included in the model had a highly significant effect on mortality at the herd level.

Table 4.2. Results of the logistic regression on cow mortality in 6,839 Danish dairy cattle herds.

Variable	Level	Odds ratio	95 % confidence interval for odds ratio
Housing system	Tie stall barn	1.04	1.00 – 1.08
	Free stall barn with cubicles	1	
	Free stall barn with deep litter	0.79	0.75 – 0.84
Use of grazing	Yes	0.78	0.74 – 0.81
	No	1	
Predominant breed	More than one breed	0.94	0.91 – 0.98
	Danish Jersey	0.93	0.87 – 0.99
	Other breeds	0.73	0.55 – 0.97
	Danish Red Dairy Breed	0.67	0.60 – 0.74
	Danish Holstein	1	
Conventional vs. organic herd	Conventional	1.17	1.07 – 1.28
	Organic	1	
Herd size		1.05*	1.03 – 1.07*
Somatic cell count		1.16#	1.14 – 1.19#
Proportion of purchased cows		1.05§	1.04 – 1.06§
Milk yield		0.93¤	0.91 – 0.94¤

*: For an increase in herd size of 50 cows
#: For an increase in average weighted mean somatic cell count of 100,000 cells per ml
§: For an increase in the proportion of purchased cows of 0.1
¤: For an increase in mean milk yield per cow year of 1000 kg ECM

Mortality risk at the herd level increased with increasing herd size, increasing proportion of purchased cows, and increasing average somatic cell count at the herd level. Mortality risk decreased with increasing average milk yield per cow. The risk was low in free stall barns with deep litter compared to those with cubicles and tie stall barns. Herds comprising Danish Holstein or Danish Jersey as the predominant breed had a higher mortality risk than those comprising Danish Red Dairy Breed. Mortality risk was lower in organic herds compared to conventional herds and in herds that were pasture grazed during the summer. The risk factors all had a relatively large effect on the predicted mortality risk in the herd.

4.3 Evaluation of the clinical protocol

Five veterinarians with experience from practice and/or research examined 283 dairy cows from four Danish dairy herds and assigned scores for the clinical signs lameness, body condition score, hock lesions, other cutaneous lesions, vaginal discharge, skin condition and general condition to each cow using the clinical protocol (Appendix 1). We evaluated the inter-observer agreement using a Bayesian threshold model and the intra-observer agreement using kappa statistics. We chose two different cut-offs between the ordinal scores for classifying cows as healthy or diseased, and we compared the ability of the observers to discriminate between healthy and diseased cows for the two cut-offs. Generally, sensitivity were higher than specificity for the 1. cut-off, while the opposite was the case for the 2. cut-off.

We concluded that the clinical protocol was easy to use (not costly nor time-consuming). Even with no formal training of the observers we considered both intra- and inter-observer agreement acceptable. Kappa values for intra-observer agreement were in the range 0.40 to 0.70 and sensitivity and specificity for inter-observer agreement were in the range 0.66 to 0.99 and 0.47 to 0.98, respectively. We therefore found the protocol suitable for use both in research and in clinical practice.

4.4 Definition, prevalence and consequences of loser cows

We studied loser cows in 39 Danish commercial dairy herds with loose-housing systems. The herds were selected randomly among herds that met certain inclusion criteria (e.g. more than 100 cows, primarily Danish Holstein, cows being milk recorded and conformation scored). Each herd was visited three times with an interval of approximately 120 days during the period September 2003 to October 2004. During each visit nearly all cows in the herd (both lactating cows and dry cows) were examined.

4.4.1 Definition

A loser cow was defined on the basis of the clinical examination of the individual cow. We developed a clinical protocol for the examination of the cows. The protocol is presented in Appendix 1. The results of the clinical examination were converted into a loser cow score. The conversion into points for the loser cow score is shown in Table 4.3. The loser cow score was defined as the sum of the points for each of the seven clinical signs. In this way each cow observed was assigned a loser cow score ranging from 0 to 32.

Table 4.3. Conversion of the clinical scores into points for a 'loser cow score' in a Danish study of loser cows. Points are shown as the raised numbers for each clinical score.

Lameness	1^0 2^1 3^2 4^4 5^8
Body condition score	1^0 2^0 3^4 4^8
Hock lesions	1^0 2^0 3^1 4^2
Other cutaneous lesions	1^0 2^0 3^1 4^2
Vaginal discharge	1^0 2^2
Skin condition	1^0 2^1 3^2
General condition	1^0 2^4 3^8

We wanted to classify cows as loser cows or non loser cows. We evaluated the consequences on milk production, mortality, culling, morbidity and workload for the farmer for different definitions of a loser cow. We changed the definition of a loser cow by changing the minimum loser cow score that was needed for a cow to be classified as a loser cow. A loser cow score of 8 was chosen as the threshold: Cows with a loser cow score of 8 or more were classified as loser cows.

4.4.2 Prevalence of loser cows

The overall prevalence of loser cows among the 15,151 cows examined was 3.24 %. The prevalence of loser cows in the 39 herds ranged from 0 % to 11.5 % (Q1: 0.68; median: 1.89; Q3: 3.04). The distribution of loser cow scores for the 15,151 cows is presented in Figure 4.5.

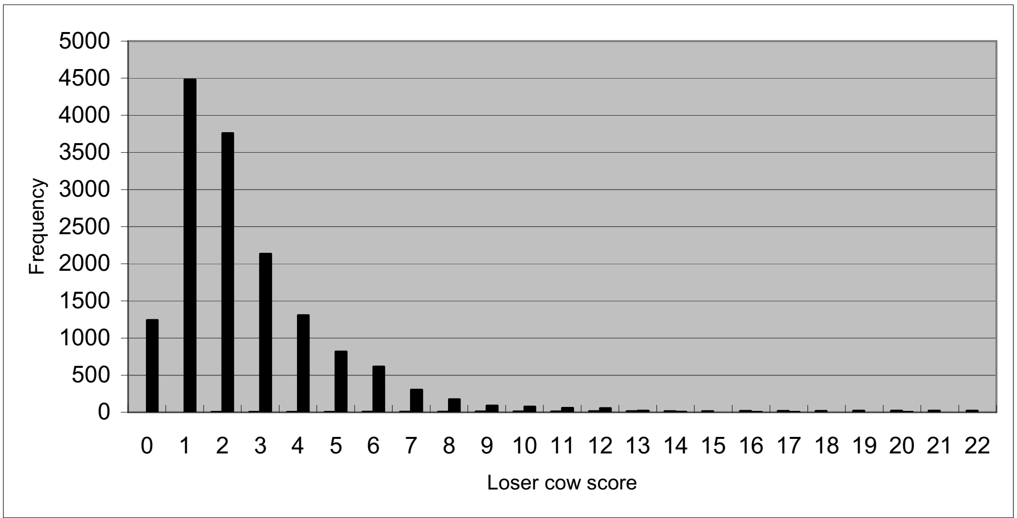

Figure 4.5. Distribution of loser cow scores for 15,151 Danish dairy cows from 39 herds.

The mean loser cow score was 2.53, the minimum loser cow score observed was 0 and the maximum loser cow score observed was 22. Figure 4.6 shows the mean loser cow score in each of the 39 herds.

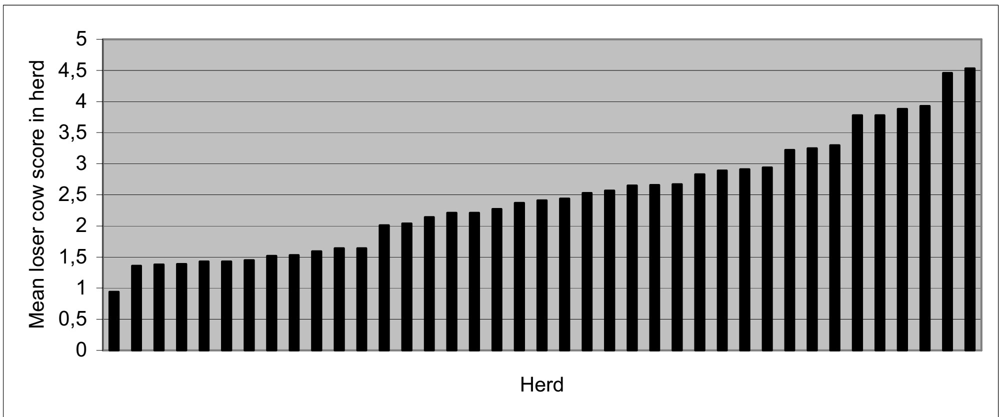

Figure 4.6. Mean loser cow score in each of the 39 Danish dairy herds in a study of loser cows.

We evaluated the effect of season on the prevalence of loser cows and found that the mean loser cow score was lowest during summer (June – August) and highest during spring (March – May).

4.4.3 Consequences of the loser cow state

Our hypothesis was that milk production, mortality, culling, morbidity and workload for the farmer were negatively affected by the loser cow state. To evaluate this hypothesis we examined the relation between the loser cow state and milk production, mortality, culling, diseases and workload.

4.4.3.1 Milk production

Generally, milk production was negatively affected by the loser cow state. Loser cows reached peak milk yield earlier than non loser cows in parity 1. The average daily milk yield during the lactation was reduced significantly for all parities. On average loser cows yielded 0.64, 2.24 and 1.52 kg ECM per day less than non loser cows during first, second and later lactations, respectively.

4.4.3.2 Mortality

The relation between the loser cow state and mortality was evaluated using a Cox proportional hazards model. The outcome was survival time in days from calving to death or euthanasia. The hazard ratio for death or euthanasia was 5.69 (95 % confidence interval: 3.93 – 8.23) for loser cows compared to non loser cows. Loser cows thus had a significantly higher mortality than non loser cows.

4.4.3.3 Culling time

The relation between the loser cow state and the time from calving to culling (death, euthanasia or slaughter) was evaluated using a Cox proportional hazards model. The outcome was survival time in days from calving to slaughter, death or euthanasia. The hazard ratio for culling was 2.55 (95 % confidence interval: 2.00 – 3.26) for loser cows compared to non loser cows.

4.4.3.4 Culling mode

Culling mode was recorded by the farmer each time a cow left the herd. The farmer used the categories dead, euthanised, slaughtered or sold for dairy purposes. Table 4.4 summarises the culling modes for loser cows and non loser cows, respectively.

Table 4.4. Distribution of culling modes for 1314 culled cows in a study of loser cows in Danish dairy herds.

	Percent dead	Percent euthanised	Percent slaughtered	Percent sold for dairy purposes
Non loser cows	5.8	4.4	86.4	3.4
Loser cows	15.4	13.5	69.2	1.9

A significantly larger proportion of the loser cows left the herds in an ‘unfavourable way’ compared to non loser cows.

4.4.3.5 Workload

Workload was recorded by the farmer each time a cow left the herd. The farmer assessed the workload associated with the cow as either ‘no extra work compared to an average cow in the herd’, ‘a little extra work’ or ‘much extra work’. Table 4.5 summarises the workload associated with loser cows and non loser cows, respectively.

Table 4.5. Distribution of the farmers assessment of the amount of work associated with 1314 culled cows in a study of loser cows in Danish dairy herds.

	Percent with 'no extra work'	Percent with 'a little extra work'	Percent with 'much extra work'
Non loser cows	74.1	19.6	6.3
Loser cows	53.9	30.8	15.4

In general, the farmers experienced a greater workload with loser cows compared to non loser cows.

4.4.3.6 Diseases

We analysed the effect of the loser cow state on the number of disease treatments in the lactation where the cow was observed using a Poisson regression model. The incidence rate ratio (IR) for disease treatments (all diseases) was 0.69 (95 % confidence interval: 0.55 - 0.86) for non loser cows compared to loser cows and the IR was 0.56 (95 % confidence interval: 0.44 – 0.70) for all diseases excluding mastitis. Thus, the number of disease treatments among non loser cows was significantly lower than among loser cows.

4.4.4 Alternative definitions of loser cows

Clinical signs with a low prevalence of deviations from the normal condition were omitted in a 'simple loser cow score'. The simple loser cow score included 4 clinical signs: lameness, hock lesions, other cutaneous lesions and skin condition. We concluded that the simple loser cow score in the vast majority of cases defined the same cows as loser cows as did the original loser cow score. The simple loser cow score is easier to use and is therefore recommended for future research and use in practice.

We evaluated the relation between the new 'diagnosis' loser cow and lameness. We found that the negative consequences of being a loser cow were considerably larger than the negative consequences of being a lame cow. We therefore concluded that the loser cow score (and, hence, the concept of loser cows) is relevant as loser cows are different from, and more than just, lame cows.

4.5 Risk factors for loser cows

Risk factors for the loser cow state were evaluated both at the herd level and at the cow level. Information about potential risk factors were collected both from the Danish Cattle Database and during visits to the 39 herds included in the study.

4.5.1 Correspondence analysis

We used correspondence analysis to give a first indication of the associations between the proportion of loser cows in the herd and potential risk factors. The first two dimensions of the correspondence analysis accounted for 23.4 % (12.3% and 11.1 %, respectively) of the spatial variation in the data. A high proportion of loser cows seems to be associated with a high proportion of stillborn calves, a high calf mortality, a high average somatic cell count and no grazing. A low proportion of loser cows on the other hand seems to be associated with the use of grazing, intermediate somatic cell count, a low proportion of stillborn calves and small herds.

4.5.2 Herd level risk factors

To give an 'overall picture' of the management and the physical characteristics of the herds we chose 1-4 explanatory variables regarding each of the main areas: Management, farmer's attitude, physical facilities, hygiene, production results, farmer's experience and herd size.

The final logistic regression model at the herd level included the explanatory variables stall surface, use of grazing and average somatic cell count in the herd. There was a statistically significant interaction between stall surface and use of grazing. The results are summarised in Table 4.6.

Table 4.6. The final logistic regression model in a study of herd level risk factors for loser cows including 5,097 cows from 39 Danish dairy cattle herds.

Variable	Level	Odds ratio	95 % confidence interval for odds ratio	p-value
Average somatic cell count		1.81#	1.37-2.39#	<0.0001
Stall surface * use of grazing	Soft cubicles and grazing	0.09	0.04-0.23	<0.0001
	Hard cubicles and grazing	0.45	0.30-0.69	
	Soft cubicles and no grazing	0.78	0.38-1.61	
	Hard cubicles and no grazing	1		

#: For an increase in average somatic cell count of 100,000 cells per ml

4.5.3 Cow level risk factors

We used a random effects logistic regression model to evaluate potential cow level risk factors for the loser cow state. The results of the logistic regression at the cow level are summarised in Table 4.7.

Table 4.7. The final logistic regression model in a study of cow level risk factors for loser cows including 6,451 cows from 39 Danish dairy cattle herds.

Variable	Level	Odds ratio	95 % confidence interval for odds ratio	p-value
Parity	1	0.16	0.10-0.26	0.0036
	2	0.41	0.27-0.62	
	3 or older	1		
Height		1.20§	0.92-1.57§	0.1245
Breeding value for milk production		0.76#	0.60-0.97#	0.0632

§: For an increase in height of 5 cm

#: For an increase in breeding value for milk production of 5 units

The final model included parity as an explanatory variable. Odds ratio for the loser cow state increased significantly with increasing parity. Additionally, height and breeding value for milk production had p-values over 0.05, but below 0.15. There was a tendency for higher odds ratio for the loser cow state with increasing height and lower odds ratio with increasing breeding value for milk production.

4.5.4 Conclusions

Herds with a high average somatic cell count, a high calf mortality, many stillborn calves, hard cubicles and no grazing seem to be associated with a high proportion of loser cows. Additionally, older cows seem to be at greater risk than younger cows.

5. Mortality (including euthanasia) among Danish dairy cows (1990-2001)

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Mortality (including euthanasia) among Danish dairy cows (1990–2001)

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Abstract

Mortality among Danish dairy cows was examined using data from the Danish Cattle Database (DCD) and a questionnaire survey. Mortality risk has increased from approximately 2% in 1990 to approximately 3.5% in 1999. The increased mortality was seen for all dairy breeds and all age groups. Mortality among older dairy cows (parity 3 and older) was approximately twice the mortality among younger cows. 30–40% of deaths were during the first 30 days of the lactation.

Approximately, 58% of dead dairy cows had been euthanised. Replies from the questionnaire indicate that the proportion of euthanised cows has increased in the past 5 years. In 86% of all deaths (questionnaire survey) a primary reason could be identified; 25% were for locomotor disorders.

Keywords: Dairy cow; Mortality; Euthanasia; Questionnaire; Cause of death; Denmark

1. Introduction

Mortality among dairy cows constitutes a problem both in terms of financial losses (value of dead cows, decreased production and extra labour) and compromised animal welfare (suffering before death or euthanasia). A rise in the mortality among a group of

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cows can indicate sub-optimal health and welfare. Only a few studies focusing on mortality among dairy cows exist (Harris, 1989; Gardner et al., 1990; Menzies et al., 1995; Faye and Perochon, 1995; Stevenson and Lean, 1998; Nørgaard et al., 1999).

The number of adult cattle processed at the Danish incineration plants has increased from 31,785 in 1990 to 42,887 in 2001, while the number of annual calvings has decreased from 946,000 in 1990 to 829,000 in 2001 (Andersen and Lauritsen, 2002). In these statistics, no distinction between dairy cows, beef cows or bulls has been made. However, these figures indicate an increasing mortality during the last 10 years.

It is unknown how many cows die unassisted and how many are euthanised and whether there has been an increase in the number of euthanised cows over the years. Decreasing average profits per cow, decreasing value of the individual cow, increasing labour costs and increasing veterinary expenses (Anonymous, 2002) might have affected the farmer's decision-making concerning treatment versus euthanasia. Thus, the farmer's interest in intensive treatment of seriously ill cows might have decreased, resulting in more euthanasia and a decrease in expensive treatments (e.g. operations for left-displaced abomasums). To our knowledge, no historic data on the proportion of euthanised dairy cows (in relation to cows dying unassisted) exist. An analysis of the development of the proportion of euthanised cows over time is therefore not possible. However, it is possible to retrieve information on the current proportion of euthanised cows by means of a questionnaire survey combined with a question about the farmers' subjective opinion of changes in their practice concerning euthanasia over the past 5 years.

Our objectives were to quantify the development in mortality among Danish dairy cows during 1990–2001, examine the distribution of deaths during the lactation, examine the effect of parity on mortality, examine the reasons for deaths and determine the proportion of mortality due to euthanasia in 2002.

2. Materials and methods

2.1. Data from the Danish cattle database (DCD)

The DCD is managed by the Danish Cattle Federation. DCD contains registrations from the farmers, dairies, slaughterhouses, veterinarians, cattle-breeding organisations and laboratories. Registrations include e.g. pedigree, breeding values, meat-quality data, meat-inspection data, disease treatments, services, calvings, movements, deaths, milk yield and milk composition (fat, protein, somatic-cell count, etc.) for individual cows. Besides registrations about individual cows, DCD also contains information about herds (e.g. size, location and health status concerning certain infectious diseases). All farmers, veterinarians, etc. are required by law to report data to DCD (Houe et al., 2003).

Data from DCD concerning all cows of dairy breeds (Danish Holstein, Danish Red Holstein, Danish Jersey, Finnish Ayrshire and Danish Red Dairy Breed) were drawn using a SAS-program (Statistical Analysis System, version 8.2). All cows calving between 1 January 1990 and 31 December 2001 were included in the study (7,206,629 lactations). For every calving, the fate of the cow was classified as either: (1) the cow died during the lactation or the subsequent dry period or (2) the cow completed the lactation and calved again in the herd, was sold for dairy purposes or was slaughtered. The fate of the cow for the first 100 days of the lactation was classified as either: (a) sold for dairy purposes within the first 100 days of the lactation (these cows were censored), (b) slaughtered within the first 100 days of the lactation, (c) died during the first 100 days of the lactation or (d) alive in the herd for the first 100 days of the lactation.

2.2. *Data control and editing*

Cows with parities >15 were not included in the study. Some information was registered in more than one way. Slaughter of a cow was e.g. registered both by the farmer and by the slaughterhouse, a dead cow was registered both by the farmer and by the incineration plant and transfer between two herds was registered both in the herd from which the cow left and in the herd the cow entered. Agreement between this information was investigated. Only cows with double entries were included in the study. Three types of registration errors were identified and the respective observations were omitted: (1) Cows calving before the 1 January 2000 with no subsequent calving, death, sale or slaughter registered were identified. In 1990, 1991 and 1992 these cows constituted 2.98, 2.43 and 0.62% of all cows, respectively, but in 1993–1999 only 0.04–0.58% with the highest numbers in the most recent years. Registration procedures were changed in 1993. It is likely that a few cows calving in, e.g., 1999 have not calved, died, been sold or slaughtered subsequently—whereas it is unlikely that cows calving in, e.g., 1990 have not calved, died, been sold or slaughtered subsequently. Cows calving in 1990, 1991 and 1992 with this error were not included in the study. (2) Cows calving in a new herd without any transfer between herds being registered were not included in the study. These cows made up $<0.05\%$ of all cows. (3) Cows slaughtered are registered both by the farmer and by the slaughterhouse. If the number of days between these two registrations exceeded 30, the cow was not included in the study. These cows made up $<0.005\%$ of all cows. Apart from this, no data editing took place.

During the years 1990–1997, registration of dead cows took place primarily in herds participating in the Danish milk-control programme. Not until 1997 did the registration of dead cows from all Danish herds become mandatory. In 2002, 88% of all Danish dairy herds (constituting 93% of all Danish dairy cows) participated in the milk-control programme. To control the influence of this on our data, we compared data from the cows included in the study with data from cows from herds participating in the Danish milk-control programme. We found no significant differences between the two populations of cows regarding any of the parameters studied.

2.3. *Statistical analysis*

Because the risk of dying varies during the lactation, we chose to use the number of calvings as the denominator (and, hence, calculate the mortality risk). Mortality risk for each year was calculated as the number of cows dying out of the total number of cows calving during that year.

A survival analysis for the years 2000 and 2001 was performed using the PROC PHREG procedure of SAS (Statistical Analysis System, version 8.2). Each breed was analysed separately. Days from calving to death were included in the model and the cows were stratified according to parity (parity 1, 2, 3, 4 or 5 and older).

2.4. Questionnaire

The proportion of euthanised cows was studied in a questionnaire survey. A total of 196 farmers were interviewed over the telephone. The necessary number of interviews was calculated according to the following equation (Toft et al., 2003):

$$n = (Z_{1-\alpha/2})^2 \times \frac{p(1-p)}{L^2}, \qquad (1)$$

where n is the number of interviews, $Z_{1-\alpha/2}$ is 1.96 for a confidence level of 95%, p the probability for euthanasia and L the maximum allowable error. p was unknown at the start of the study and p was set at 0.5 because $p = 0.5$ gives the highest possible sample size. We set the maximum allowable error to 0.07. Therefore

$$n = 1.96^2 \times \frac{0.5(1-0.5)}{0.07^2} = 196 \qquad (2)$$

The questionnaire study was carried out from 18 October 2002 to 13 December 2002.

No later than 7 days after a death of a cow, the farmer must report the incident to the DCD. Every Tuesday, 28 dead cows were drawn by simple random sampling from the DCD by a SAS-program (Statistical Analysis System, version 8); four cows that had died every day from 11 to 17 days prior to the sampling day were drawn. In this way, an equal number of cows which had died every day of the week was sampled. Different practices concerning euthanasia during weekends might exist. Veterinary costs are higher during weekends and this might increase the number of cows shot by the farmer without prior veterinary examination and treatment. The effect of this was included in our study by making sure that cows that had died during the weekend constituted 2/7 of the cows included in the study.

The study population was all Danish cows of dairy breeds (Danish Holstein, Danish Red Holstein, Danish Jersey, Finnish Ayrshire and Danish Red Dairy Breed). The sampling unit was individual cows. After the sampling, all cows were checked regarding the herd of origin. Only cows of dairy breeds and currently in commercial milk-producing herds were included. Two cows from one herd stamped out because of BSE were drawn and omitted. Cows from educational or experimental herds were not included in the study, either.

At the day of sampling, a letter of introduction was sent to the farmers. The letter explained the background and purpose of the study and guaranteed confidentiality. The farmer was then contacted by telephone 2–7 days later. Consequently, the farmers were interviewed about a death that occurred 2 to 3 weeks prior to the interview. In this way, we hoped that recall bias was minimized. If we were not able to reach the farmer by phone at the first attempt, we tried again for several days—four times, altogether. If we did not get in contact with the farmer, he/she was censored. The study continued until 196 farmers had been interviewed. Farmers were asked to give the primary reason for death or euthanasia without any categorization. The primary reason stated by the farmer

Table 1
Primary reasons for unassisted death or euthanasia of dairy cows as stated by the farmer in a Danish questionnaire survey

Primary reason	Unassisted dead cows (% of $n = 82$)	Euthanised cows (% of $n = 114$)
Accident	5	12
Calving disorder	10	7
Digestive disorder	17	11
Locomotor disorder	2	40
Metabolic disorder	15	8
Udder/teat disorder	11	8
Other	12	10
Unknown	28	4

was then categorized by a veterinarian into one of the categories shown in Table 1. A comprehensive list of how to categorize reasons was made. If the farmer could not state a primary reason, the reason was recorded as ‘unknown’. The category ‘other’ includes reasons not fitting into any of the other categories. The farmers were asked their subjective opinion regarding changes in their practice concerning euthanasia over the past 5 years. They were asked if they euthanise relatively more cows (expressed as the percentage of cows in the herd euthanised per year) now than 5 years ago, euthanise the same relative number of cows or euthanise relatively fewer cows now than 5 years ago. If the farmer had started his/her operation <5 years ago, the question was classified as ‘not relevant’.

2.5. Validation of questionnaire data by examination at incineration plant

Validation of the results was desired, because no other information about the proportion of euthanised cows exists. Examination of dead cows at incineration plants would not provide a correct proportion of euthanised cows. Some of the euthanised cows were killed by an overdose of an anaesthetic (e.g. a barbiturate) and some were shot. The cows given an overdose of an anaesthetic cannot be distinguished at the incineration plant from cows which died unassisted. It is therefore not possible to determine the proportion of euthanised cows simply by determining the proportion of shot cows. However, the proportion of cows at an incineration plant killed by gunshot can be compared to the proportion of cows from the questionnaire and killed by gunshot. A sample of 196 dead dairy cows was examined at an incineration plant, where all dead adult cattle in Denmark are processed. The number of cows was calculated according to Eq. (1). To take into account a possible altered practice concerning euthanasia during the weekend, 2/7 of the cows were examined on a Monday. 70 dairy cows (defined as adult cows of dairy breed with a well-developed udder) were examined on Wednesday the 6 November 2002, 70 dairy cows were examined on Friday the 8 November 2002 and 56 dairy cows were examined on Monday the 11 November 2002. A veterinarian noted whether the cow was shot in the forehead or not. The first cow so-examined each day was selected at random and then this and the following 69, 69 and 55 cows, respectively, were examined.

3. Results

3.1. Data from the DCD

Danish Holstein constituted 72.6% of the 7,206,629 calvings in the period 1990–2001, Danish Jersey 14.7%, Danish Red Dairy Breed 11.5% and Danish Red Holstein 1.2%. Mortality risk (including both unassisted dead and euthanised cows) for the whole lactation and the subsequent dry period among Danish dairy cows from 1990 to 1999 is presented in Fig. 1. Mortality risk during the first 100 days of the lactation (Fig. 2) is also shown because this figure can be calculated 100 days after the 31 December 2001 for the year 2001, whereas mortality risk during the entire lactation for the year 2001, cannot be calculated until all cows calving in 2001 have either calved again, died, been sold for dairy purposes or slaughtered. Both figures show risks to be increasing in a parallel manner for the three breeds over the years. Mortality risk for the first 100 days of the lactation was ∼60% of the total mortality risk during the lactation.

Mortality risk during the first 100 days of the lactation for Danish Holstein cows increased for all parities during the years. The increase seems parallel for all parity groups, but the risk among the cows of parity ≥ 3 is approximately twice that of the younger cows (Fig. 3). The trend was the same for the other dairy breeds, also (data not shown).

Survival after calving for Danish Holstein is presented in Fig. 4. Differences between all parities of Danish Holstein are highly significant ($P < 0.0001$). Results for the other breeds are not shown, but are similar to the results shown for Danish Holstein.

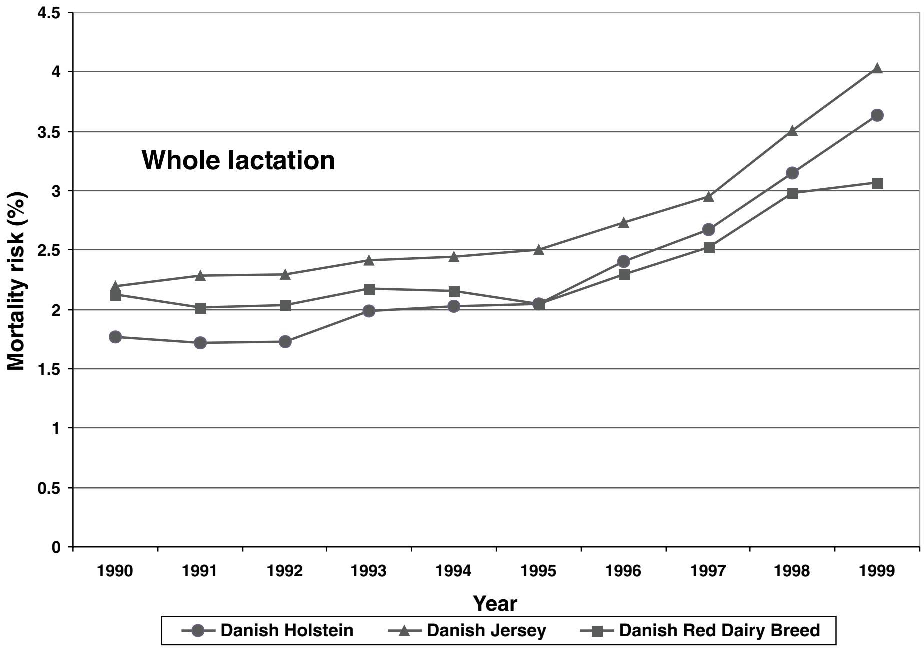

Fig. 1. Breed-specific mortality among Danish dairy cows, 1990–1999.

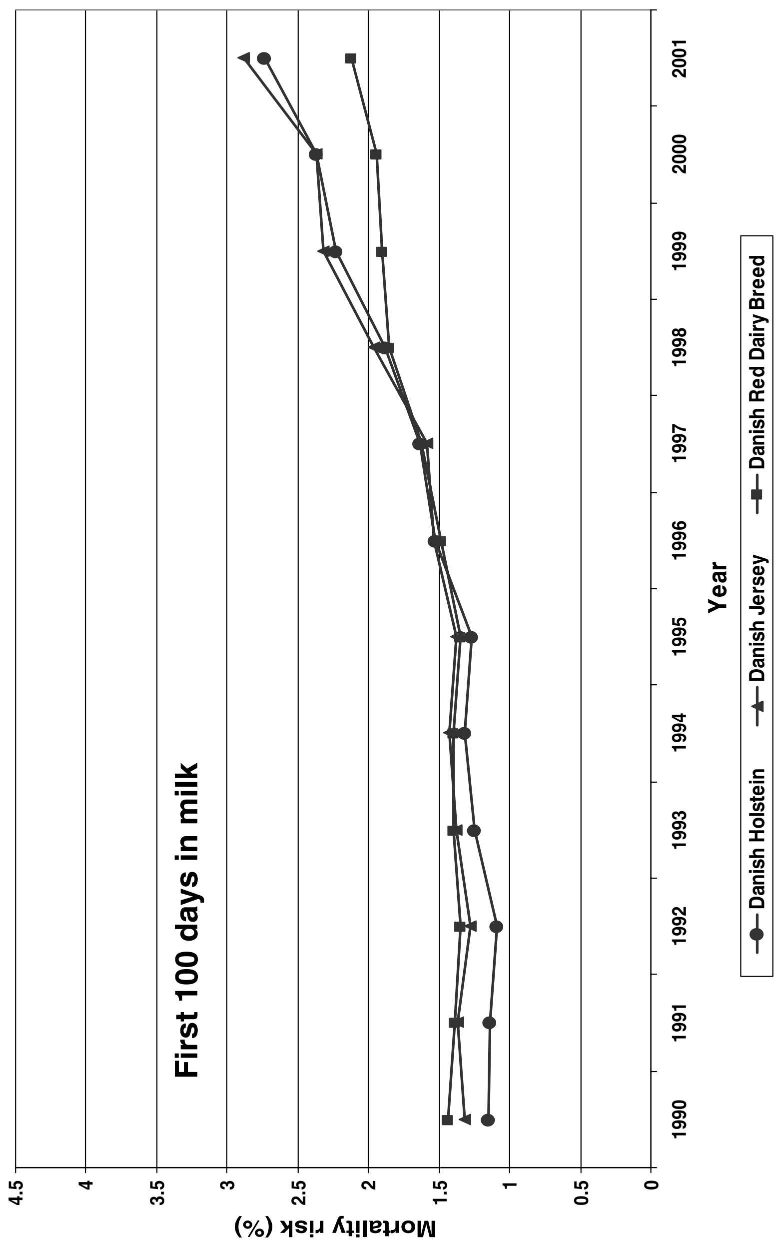

Fig. 2. Breed-specific mortality during the first 100 days of the lactation among Danish dairy cows, 1990–2001.

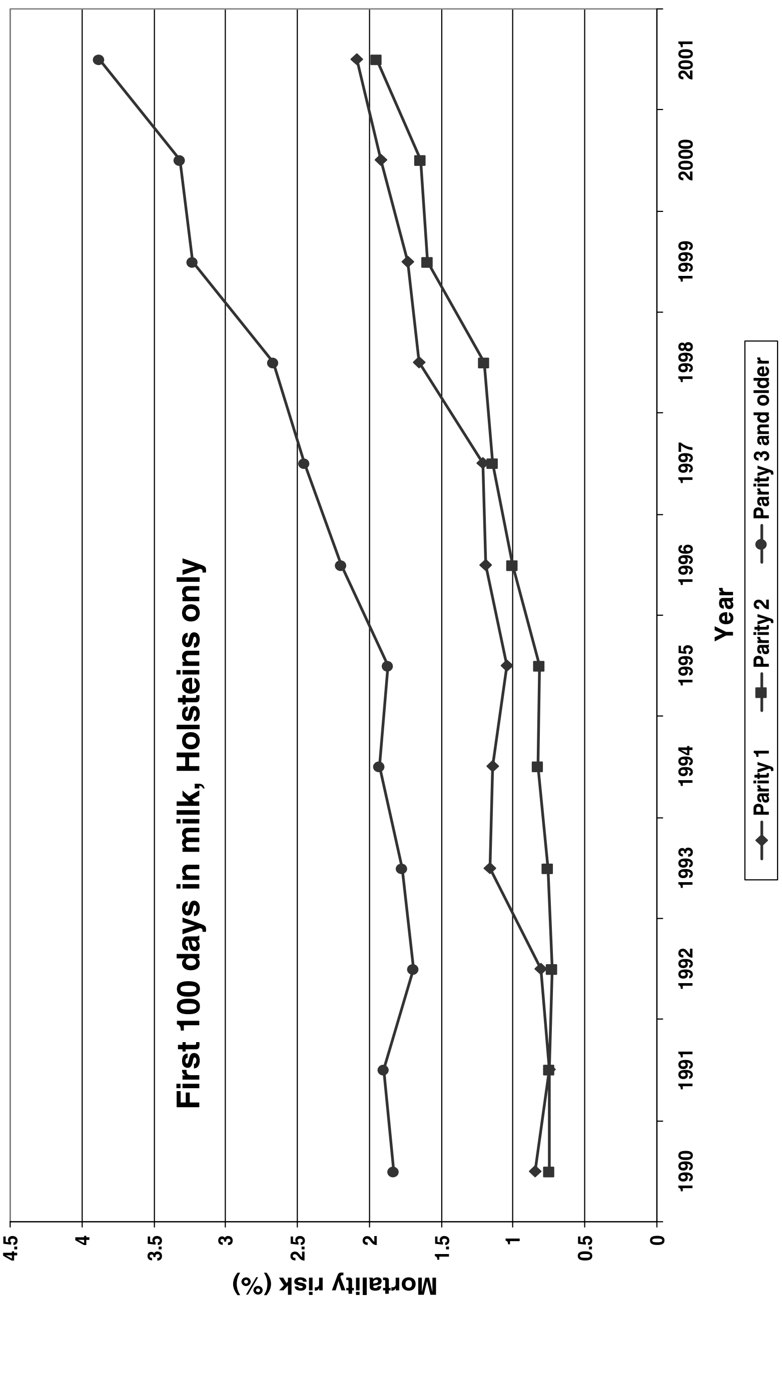

Fig. 3. Parity-specific mortality among Danish Holstein cows during the first 100 days of the lactation, 1990–2001.

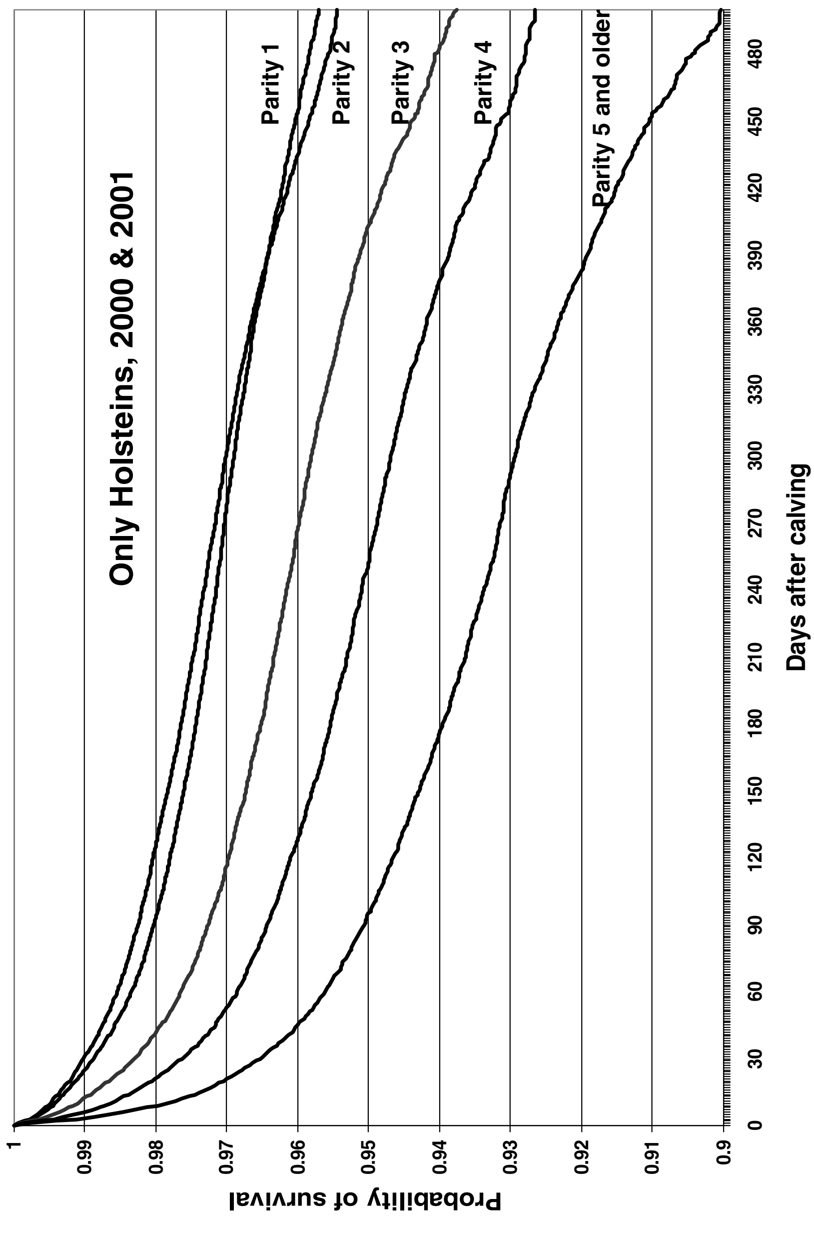

Fig. 4. Parity-specific survival after calving for Danish Holstein cows for the years 2000 and 2001.

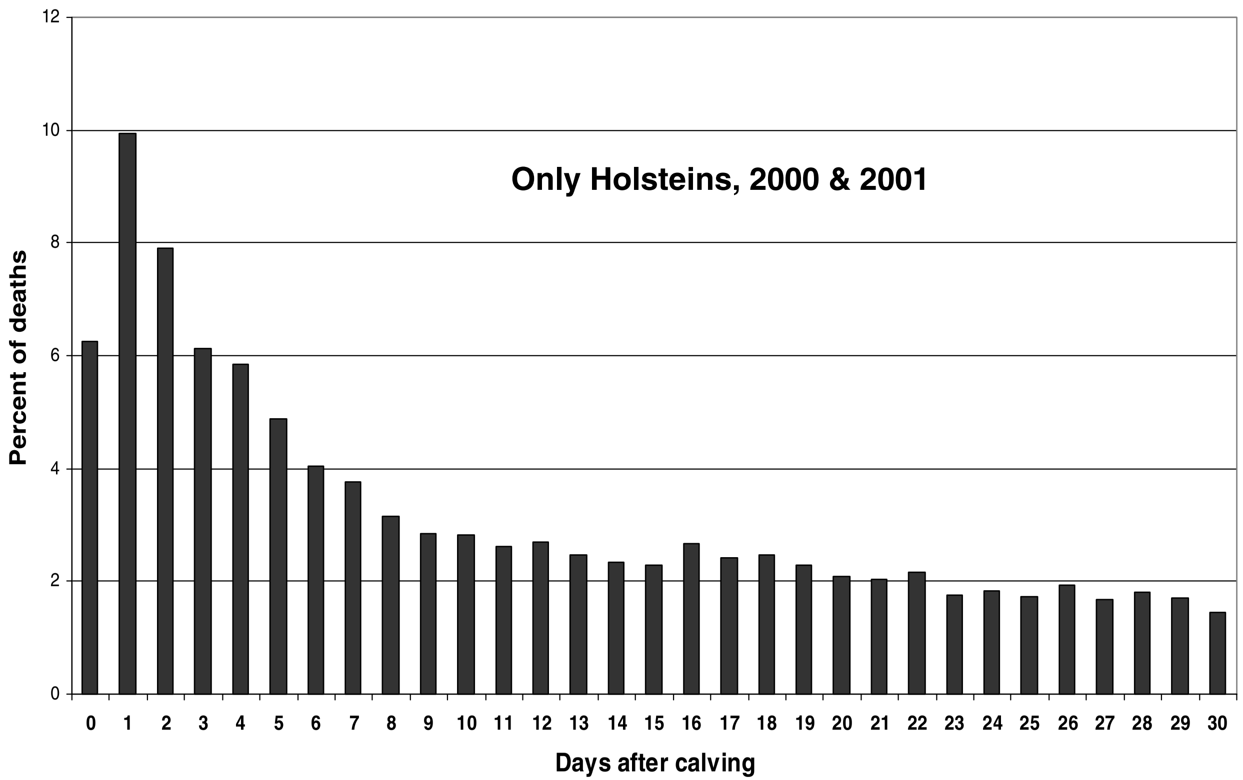

Fig. 5. Distribution of deaths in days after calving during the first 30 days of the lactation among Danish Holstein for the years 2000 and 2001, all parities.

30.5% of the dead young (parity 1 and 2) Danish Holstein cows died during the first 30 days of the lactation compared to 41.1% of the older cows. Among Danish Red Dairy Breed, the proportion of early deaths was 33.2% of the dead younger Danish Red Dairy Breed cows and 45.4% of the dead older cows. During the first 30 days of the lactation, the distribution of deaths is uneven—with the highest mortality during the first few days after calving (Fig. 5).

3.2. Questionnaire

Out of 208 farmers, 196 farmers (94.2%) answered the questionnaire, two farmers (1.4%) refused to take part in the study and 10 farmers (4.8%) were not reached by phone despite several attempts.

Median herd size among the herds in the study was 106 cows (minimum: 27; first quartile: 70; third quartile: 136; maximum: 564). 59.2% of the herds consisted of mainly (>90% of the cows in the herd) Danish Holstein (median herd size 108), 11.7% were mainly Danish Jersey (median herd size 125), 3.1% were mainly Danish Red Dairy Breed (median herd size 70) and 26.0% were herds with more than one breed (median herd size 86).

Of the dead cows, 41.8% died unassisted and 58.2% were euthanised. 42.5% of these were euthanised by a veterinarian, 45.1% were euthanised by the farmer and 12.4% were euthanised by others (mainly salvage corps). 76.8% of the euthanised cows were shot and 23.2% were euthanised by an overdose of an anaesthetic. It is worth noting that euthanasia by the use of an overdose of an anaesthetic is not allowed for layman in Denmark.

The primary reasons for euthanasia or death as stated by the farmer are presented in Table 1. 55.9% of the cases were stated to be acute, 42.6% were stated to be chronic and in 1.5% of the cases no statement about the time course was obtained.

More than half (54.6%) of the farmers stated that they euthanised relatively more (expressed as the percentage of cows in the herd euthanised per year) cows now than 5 years ago, 40.3% euthanised the same relative number of cows now as then and 2.0% euthanised relatively fewer cows now than 5 years ago. In six cases (3.1%), this question was not relevant.

Out of the 196 cows examined at the incineration plant, 52% were shot. Results from the questionnaire state that 58.2% of the cows were euthanised and that 76.8% of these were shot. The percentage of cows from the questionnaire shot is therefore $58.2\% \times 0.768 = 44.7\%$. The 95% confidence intervals for the proportion of shot cows for the two studies are (38%, 52%) for the questionnaire and (45%, 59%) for the examination at the incineration plant.

4. Discussion

We found an increase in mortality risk among Danish dairy cows from approximately 2% in 1990 to 3.5% in 1999. Reasons behind this increase in mortality were not investigated in our study, but might for a great part be explained by an increasing number of euthanised cows. Nørgaard et al. (1999) found an increase in the crude death rate among Danish cattle from approximately 2% in 1934–1960 to 3–4% in 1974–1993. They used the number of dead mature cattle brought to incineration plants as the numerator—but this number included in addition to dairy cows heifers older than 1 year, beef cows and bulls older than 10 months. Harris (1989) found mortalities ranging from 1.09 to 1.40% depending on age group in a study among New Zealand dairy cows. Karuppanan et al. (1997) found mortality rates calculated by a weighted-slope method between 1.2 and 4.2% for nine Californian dairy herds. 1.2% of 7763 lactation studies by Milian-Suazo et al. (1989) ended in death. Esslemont and Kossaibati (1997) found an annual mortality rate of 1.6% among 50 Holstein Friesian herds in England. Faye and Perochon (1995) found an annual mortality rate of 0.96% among 47 herds in Brittany. Stevenson and Lean (1998) found a mortality of 4.3% among eight dairy herds in New South Wales, Australia. Menzies et al. (1995) found an annual mortality rate of 1.6% in a questionnaire involving 1069 dairy herds in Northern Ireland. Gardner et al. (1990) found an annual mortality rate of 2% among 43 Californian dairy herds.

Direct comparisons of the mortalities found in different studies are difficult. Mortality can be calculated per cow year or per lactation (mortality rate versus mortality risk). In some studies, the exact method was not specified. Furthermore, local conditions with respect to e.g. costs of replacement cows, slaughter values, veterinary costs, husbandry practices and management can influence mortality.

In our study, 30–45% of all deaths were registered during the first 30 days of the lactation. Our findings are in good agreement with the results of Milian-Suazo et al. (1988), Faye and Perochon (1995), Menzies et al. (1995) and Stevenson and Lean (1998), who all found a high proportion of deaths during the first 15–30 days of the lactation. The periparturient period is a high-risk period for many diseases (Shanks et al., 1981; Dohoo et al., 1983; Markusfeld, 1993). Many of the diseases that were stated as primary reasons for unassisted death or euthanasia in the questionnaire survey are closely related to the periparturient period, e.g. milk fever, left- and right-displaced abomasums, mastitis caused by *E. coli*, calving disorders and locomotor disorders. Locomotor disorders were the most frequently stated cause of unassisted death or euthanasia in the questionnaire survey. Green et al. (2002) found that the risk of locomotor disorders were highest during the first 3 months of the lactation. Shanks et al. (1981) found the highest amount of health costs during the first 30 days postpartum. They concluded that the largest costs and most disorders were associated with initiation of the lactation rather than the period of peak daily milk production. Increased focus on the periparturient period may help to decrease the number of deaths among dairy cows in the future.

In accord with our results, Faye and Perochon (1995) also found a higher mortality among older cows. In contrast to this, Harris (1989) found no significant difference in mortality among cows of different ages. Higher mortality among older cows might partly be explained by an increased incidence of certain diseases among older cows. The incidence of, e.g., milk fever, displaced abomasum, downer cows, mastitis, uterine prolaps, retained placenta and ketosis increases with parity (Thompson et al., 1983; Erb and Gröhn, 1988; Markusfeld, 1993; Gröhn et al., 1998; Houe et al., 2001).

A primary reason was given in approximately 86% of cases. Among these, locomotor disorders were the major cause of unassisted death or euthanasia (28% of all deaths with a reason given). The proportion of cows euthanised because of locomotor disorders is high (approximately 40% of euthanised cows). Further research on the specific reasons behind this is needed.

The most frequent specific diagnose in the group udder/teat disorders resulting in unassisted death or euthanasia were septicaemic mastitis caused by *E. coli*. Milk fever constituted the majority of the diagnoses in the group of metabolic disorders and left- and right-displaced abomasums and cases of paratuberculosis constituted the majority of diagnoses in the group of digestive disorders.

Faye and Perochon (1995) found the major causes of death to be 'other reasons' (20% of deaths), metabolic disorders (18%), calving-related disorders (12%) and accidents (8%) (in 33% of all deaths, the reason was unknown). Menzies et al. (1995) found the major causes of death to be calving-related disorders (31% of deaths), mastitis (25%), other reasons (15%), digestive disorders (13%) and locomotor disorders (11%). Milian-Suazo et al. (1988) found the major causes of death to be udder disorders (22% of deaths) and other diseases (primarily metabolic disorders) (65% of deaths). Esslemont and Kossaibati (1997) found the major causes of death to be BSE (12% of deaths), mastitis (9%), other non-infectious disorders (8%), metabolic disorders (8%) and accidents (7%). In 46% of all deaths in that study, the reason was unknown.

Validation of the result from the questionnaire survey by examination at the incineration plant gave a comparable proportion of shot cows (point estimate contained within the other 95% confidence intervals). Both the questionnaire survey and (to an even greater degree) the examination at the incineration plant was carried out during a short period of time in the late fall. This might have influenced the results. Reasons for unassisted death or euthanasia may differ according to time of year. Calving among Danish dairy cows is not seasonal. Because many of the disorders stated as primary reasons for death or euthanasia are related to calving (e.g. milk fever, left- and right-displaced abomasums, mastitis caused by *E. coli*, calving disorders and locomotor disorders), we find it likely that the primary reasons for death or euthanasia and the proportion of euthanised cows are relatively unaffected by season. The farmers' subjective opinion about the development concerning euthanasia supports the hypothesis that the relative number of euthanised cows has escalated in the past 5 years. Possible explanations for this trend were given in the introduction. The increase in mortality risk seen from 1990 to 2001 might for a great part be due to an increasing number of euthanised cows. In the future, registrations concerning dead cows preferably should specify whether the cow died unassisted or was euthanised.

We find that an increase in the number of cows dying unassisted constitutes an animal welfare problem. The situation concerning euthanised cows is more complex. An increase in the number of euthanised cows might be due to an increase in the number of seriously ill cows. This situation also has negative impacts on animal welfare. If, on the other hand, the increase in the number of euthanised cows is not a consequence of increased morbidity—but caused by an altered threshold for euthanasia among farmers—it might have a positive impact on animal welfare. More seriously ill cows might be euthanised and thus not put through a (perhaps long) period of suffering associated with disease and treatment. If treatment is unsuccessful and the cow dies eventually, euthanasia right after the initial diagnose would have meant the least suffering for the cow. Euthanasia in itself is not an animal welfare problem if it is performed quickly and without suffering for the cow.

We consider 94.2% response to the questionnaire sufficiently high to avoid problems with selection bias. Median herd size in our questionnaire survey was 106 cows compared to 78 for all Danish dairy herds (Lauritsen and Lind, 2002). This difference was expected. The sampling unit in our study was individual cows. If the incidence of dead cows is the same in all Danish dairy herds, the probability of sampling a cow will be proportional to herd size. Danish dairy herds, consisting mainly of Danish Red Dairy Breed, are smaller than herds consisting mainly of other breeds or more than one breed (median 60 cows compared to 80 cows) (Lauritsen and Lind, 2002). This is in accord with the questionnaire survey, where we found the median herd size for Danish Red Dairy Breed to be smaller than herd sizes for the other breeds. We consider the predominant breeds in the herds in the questionnaire survey to be representative of the population of Danish dairy herds (51.6% Danish Holstein, 8.5% Danish Jersey, 5.7% Danish Red Dairy Breed, 33.7% with more than one breed and 0.5% other breeds) (Lauritsen and Lind, 2002).

5. Conclusion

Mortality risk among Danish dairy cows has increased from approximately 2% in 1990 to approximately 3.5% in 1999. Mortality risk has increased for all age groups over the years, but the mortality risk for older cows (parity 3 and older) is approximately twice the mortality risk for younger cows. A high proportion of deaths occur during the first 30 days of the lactation. 58% of the dead cows in the questionnaire survey were euthanised and 42% died unassisted.

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6. Herd level risk factors for cow mortality in Danish dairy cattle herds

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Summary

Herd level risk factors affecting cow mortality in Danish dairy cattle herds were studied using data from 6,839 dairy herds and analysed using logistic regression. Mean mortality risk for the first 100 days of the lactation was 2.5 %. Cow mortality risk increased with increasing herd size (OR=1.05 for an increase in herd size of 50 year cows), the proportion of purchased cows (OR=1.05 for an increase in the proportion of purchased cows of 0.1), and somatic cell count (OR=1.16 for an increase in average weighted mean somatic cell count of 100,000 cells per ml) at a herd level. It decreased with increasing average milk yield per cow (OR=0.93 for an increase in mean yield per cow year of 1000 kg ECM). The risk was low in free stall barns with deep litter (OR=0.79) compared to those with cubicles (OR=1) and tie stall barns (OR=1.04). Herds comprising Danish Holstein (OR=1) or Danish Jersey (OR=0.93) as the predominant breed had a higher mortality risk than those comprising Danish Red Dairy Breed (OR=0.67). Mortality risk was lower in organic herds (OR=1 compared to 1.17 in conventional herds) and in herds that were pasture grazed during the summer (OR=0.78).

Key words: dairy cow mortality, risk factors, herd level, logistic regression.

Introduction

Mortality among dairy cows constitutes a problem both in terms of financial losses and compromised animal welfare. Financial losses include both the value of the dead cow and cost of its replacement, decreased production and extra labour. Animal welfare problems include suffering before death or euthanasia. A rise in the mortality among a group of cows can indicate sub optimal health and welfare. Mortality risk among Danish dairy cows has increased from approximately 2 % in 1990 to 3.5 % in 1999. Results from a questionnaire survey of Danish dairy cattle farmers in 2002 indicated that the number of cows euthanised has increased during the past five years. Thomsen and others (2004) have suggested a link between these two increasing trends.

To the authors' knowledge the possible relationship between herd factors and cow mortality has been investigated sporadically. Batra and others (1971) and Smith and others (2000) investigated factors such as herd size, milk production level and cow mortality rates. The objectives of this present study were to identify herd level risk factors for cow mortality in Danish dairy cattle herds and to quantify their effects.

Materials and methods

The Danish Cattle Database (DCD) is managed by the Danish Cattle Federation. DCD contains registrations from farmers, dairies, slaughterhouses, veterinarians, cattle-breeding organisations and milk quality and veterinary laboratories. Registration data include individual cattle pedigrees, their breeding values, meat-quality data, meat-inspection data, disease treatments, services, calvings, deaths, milk yield and composition (fat, protein, somatic cell count). In addition to registrations about individual cows, DCD also contains information about herds, such as size and location. Some information that farmers are required by law to report to DCD includes e.g. information about deaths, calvings and transfer between herds (Houe and others, 2003).

Data were extracted from the DCD for all Danish dairy herds that were milk recorded from the 1st October, 2000 to 30th September, 2001. In 2002, 88 % of all Danish dairy cattle herds participated in milk recording. Data were collected only from herds comprising 10 or more cows; other herds were excluded if DCD registrations were incomplete (n=541) or herds were culled to control Bovine Spongiform Encephalopathy (n=8).

There were eight explanatory variables used to characterise each herd:

a) Categorical:

Housing system – tie stall barn, free stall barn with cubicles or free stall barn with deep litter. Registered during farm visits by employees of the Danish Milk Recording Associations in November 2000.

Use of summer grazing. Registered during farm visits by employees of the Danish Milk Recording Associations in November 2000.

Predominant breed – Danish Holstein, Danish Jersey, Danish Red Dairy Breed, several breeds within the herd or other breeds (Danish Red Holstein, Finnish Ayrshire or crossbred cattle). The predominant breed of the herd was defined as the breed that constituted more than 95 % of the cow days in the herd during the study period.

Organic or conventional. Information obtained from the Danish Plant Directorate.

b) Quantitative:

Herd size – average number of year cows during the study period. One cow remaining in the herd for one year equals one year cow.

Somatic cell count – average weighted mean somatic cell count, cells per ml.

Proportion of herd comprising cows purchased from other herds.

Mean energy corrected milk yield per year cow – energy corrected milk yield, kg ECM =

$$\frac{\text{milk yield (kg)} \times (38.3 \times \text{fat (g/kg)} + 24.2 \times \text{protein (g/kg)} + 783.2)}{3.14}$$

(Sjaunja and others, 1991).

Consistency between double registrations was checked, for example death of a cow is registered both by the farmer and by the incineration plant. This data control did not result in any observations being omitted. The data were analysed using logistic regression. The PROC GENMOD procedure in SAS was used (Statistical Analysis System, version 8.2). The outcome variable was the number of cows dying during the first 100 days of the lactation compared to the total number of cows calving in the herd during the study period. Dead cows were defined as either unexplained deaths, those dying following illness or those cows that were euthanised. Linearity between the quantitative explanatory variables and the outcome (logit (p)) was checked by categorizing the quantitative explanatory variables into six to ten levels. For each explanatory variable the levels were chosen to ensure a relative large and approximately equal number of observations (herds) at each level. Whenever this relation was linear, the explanatory variable was included in the analysis as a quantitative explanatory variable. All possible two-factor interactions were included (one by one) in the model with all the main effects. The initial model without interactions included is given by

$$\text{logit}(p)=\mu+\text{Housing}+\text{Grazing}+\text{Breed}+\text{Organic}+\alpha\times\text{herd size}+\beta\times\text{SCC}+\gamma\times\%\text{purchased}+\delta\times\text{ECM}$$

where p is the probability for a cow being dead

μ is the general mean

Housing is the fixed effect of housing system (three levels)

Grazing is the fixed effect of use of summer grazing (two levels)

Breed is the fixed effect of predominant breed (five levels)

Organic is the fixed effect of organic or conventional farming designation (two levels)
Herd size, SCC, %purchased and ECM are the continuous explanatory variables
α, β, γ and δ are slopes for the four continuous explanatory variables.

The degree of interaction of statistically significant ($p<0.05$) interactions was evaluated by comparison of the estimated probability for a cow being dead for different combinations of the interaction in question. If the differences between the estimated probabilities for a cow being dead were small for the different levels of the interaction, it was interpreted as a significant interaction without biological importance. The interaction was then removed from the model. This was further evaluated visually by plotting the estimated probabilities in relation to the variables in the significant interaction. Possible confounding was checked by calculating odds ratios (OR) for the risk factors with and without the possible confounder included in the model. All biologically plausible confounding were checked this way. Whenever the change in OR with and without the possible confounder included in the model was less than 5 % the confounding was considered of no biological interest.

Results

Data from 6,839 herds were investigated, and descriptive statistics of these are described in Tables 1 and 2.

Table 1. Descriptive characteristics of the 6,839 Danish dairy cattle herds included in a study on cow mortality in Danish dairy cattle herds.

	Median	Interquartile range
Herd size, cow years	67	48
Mean milk yield per cow year, kg ECM	8,069	1,372
Proportion of purchased cows	0.06	0.20
Average weighted mean somatic cell count, cells per ml	296,000	111,000

Table 2. Descriptive characteristics of the 6,839 Danish dairy cattle herds included in a study on cow mortality in Danish dairy cattle herds.

Predominant breed	Danish Holstein: 50 % Danish Jersey: 8 % Danish Red Dairy Breed: 5 % Other breeds*: 1 % More than one pure breed: 36 %
Housing system	Tie stall barn: 60 % Free stall barn with cubicles: 31 % Free stall barn with deep litter: 9 %
Use of summer grazing	Yes: 86 % No: 14 %
Organic vs. conventional herd	Organic: 5 % Conventional: 95 %

* Other breeds include Danish Red Holstein, Finnish Ayrshire and crossbreds.

The mortality risk during the first 100 days of the lactation is shown in Figure 1; the risk in 26.9 % of herds was zero. Mean mortality risk for the first 100 days of the lactation was 2.5 % (standard deviation= 2.5; minimum= 0; first quartile= 0; median= 2; third quartile= 3.7; maximum= 30.4).

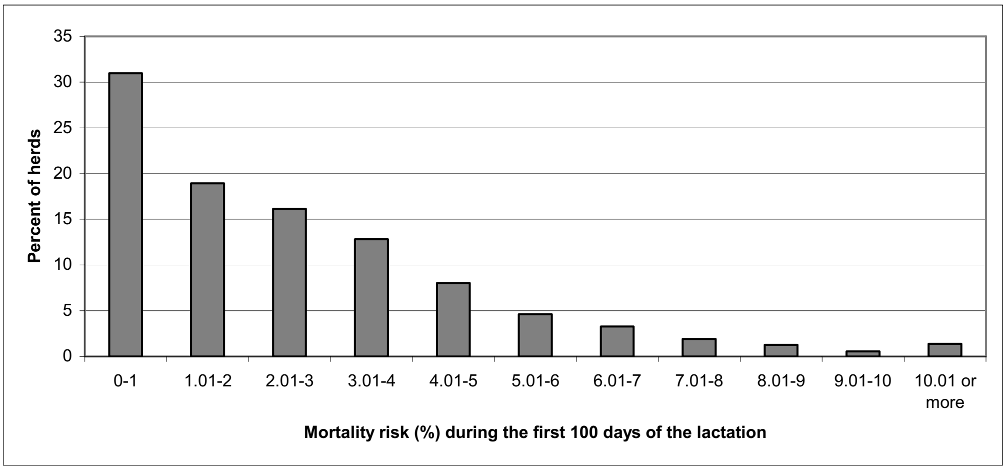

Figure 1. Distribution of mortality risk during the first 100 days of lactation in 6,839 Danish dairy cattle herds in the period 1st of October 2000 to 30th of September 2001.

Results from the logistic regression are summarised in Table 3. Effects of all explanatory variables was $p<0.001$ when they were included in the model at the same time. Linearity between the quantitative explanatory variables and the outcome (logit(p)) was considered acceptable. The overdispersion parameter was estimated at 1.24, which we considered satisfactory. No biologically important confounding was found. Statistically significant ($p<0.05$) interactions were found between nine pairs of the explanatory variables (data not shown). Figure 2 illustrates the interaction between milk yield and housing system.

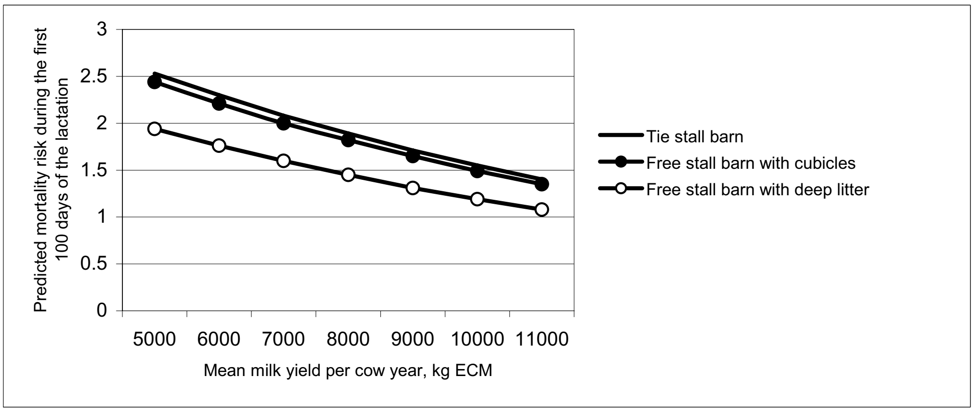

Figure 2. Predicted mortality risk during the first 100 days of lactation illustrated as a function of housing system and milk yield for conventional dairy cattle herds with summer grazing, 110 year cows, an average weighted mean somatic cell count of 230,000 cells per ml, Danish Holstein as the predominant breed and a proportion of purchased cows of zero.

Table 3. Results of the logistic regression on cow mortality in 6,839 Danish dairy cattle herds. For all variables, $p<0.001$.

Variable	Level	Estimate	SE	OR	95 % CI
Intercept		-3.550	0.107		
Housing system	Tie stall barn	0.038	0.022	1.04	1.00 – 1.08
	Free stall barn with cubicles	0.000	0.000	1	
	Free stall barn with deep litter	-0.231	0.032	0.79	0.75 – 0.84
Use of summer grazing	Yes	-0.251	0.023	0.78	0.74 – 0.81
	No	0.000	0.000	1	
Predominant breed	More than one breed	-0.060	0.020	0.94	0.91 – 0.98
	Danish Jersey	-0.074	0.034	0.93	0.87 – 0.99
	Other breeds	-0.313	0.142	0.73	0.55 – 0.97
	Danish Red Dairy Breed	-0.400	0.052	0.67	0.60 – 0.74
	Danish Holstein	0.000	0.000	1	
Conventional vs. organic herd	Conventional	0.156	0.045	1.17	1.07 – 1.28
	Organic	0.000	0.000	1	
Herd size		0.001	0.0002	1.05*	1.03 – 1.07*
Somatic cell count		0.0015	0.0001	1.16#	1.14 – 1.19#
Proportion of purchased cows		0.510	0.049	1.05§	1.04 – 1.06§
Milk yield, kg ECM		-0.0001	0.0000	0.93¤	0.91 – 0.94¤

*: For an increase in herd size of 50 year cows
#: For an increase in average weighted mean somatic cell count of 100,000 cells per ml
§: For an increase in the proportion of purchased cows of 0.1
¤: For an increase in mean milk yield per cow year of 1000 kg ECM
SE: standard error; OR: odds ratio; 95 % CI: 95 % confidence interval for OR

The predicted values of mortality risk at the herd level for various levels of the explanatory variables were calculated to estimate the biological effect of changes in the explanatory variables. All explanatory variables had a relatively pronounced effect on the predicted value of the mortality risk within biologically meaningful ranges. As an example, the predicted values of the mortality risk during the first 100 days of the lactation for different levels of average milk yield, somatic cell count and housing system are shown in Figure 3.

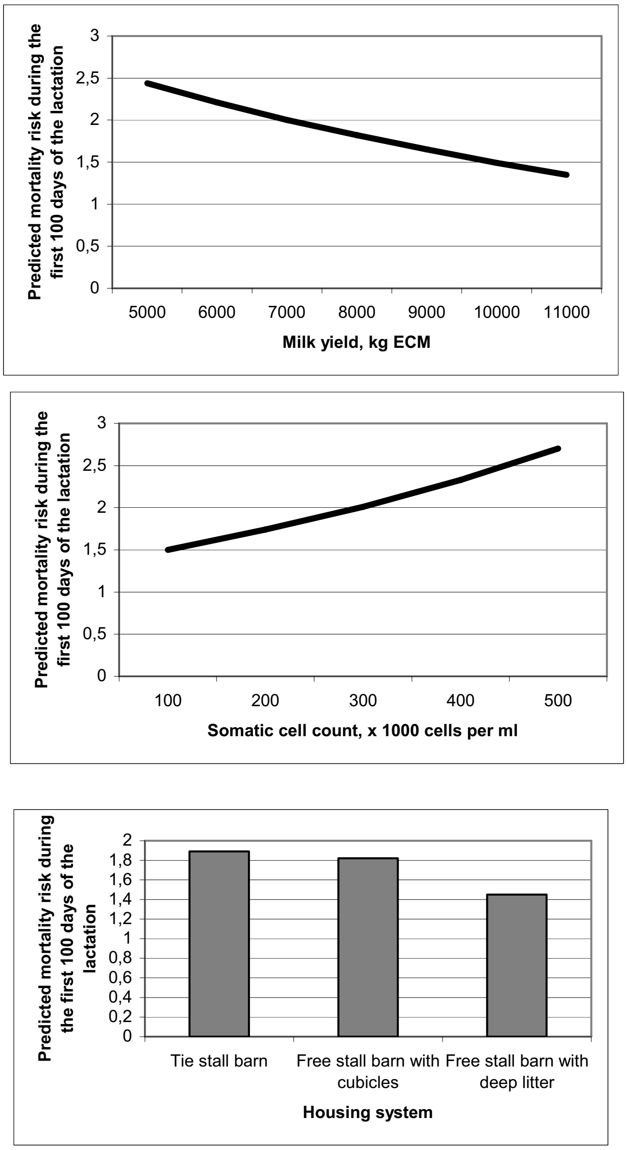

Figure 3. Predicted values of the mortality risk during the first 100 days of lactation for different levels of a) milk yield, b) somatic cell count and c) housing system. Other variables are held fixed: Danish Holstein as the predominant breed, free stall barn with cubicles, conventional herd with summer grazing, 110 year cows, mean milk yield of 8,000 kg ECM per cow year, an average weighted mean somatic cell count of 230,000 cells per ml and a proportion of purchased cows of zero.

Discussion

Selection of the outcome variable, mortality risk during the first 100 days of the lactation, was based on the fact that this figure can be calculated 100 days after the 30th September, 2001, for the study period. The mortality risk during the entire lactation cannot be calculated until all cows calving in the study period have either calved again, died, been sold for dairy purposes or slaughtered. By using this variable, more up-to-date figures can be shown. Thomsen and others (2004) calculated that mortality risk for the first 100 days of the lactation constituted approximately 60 % of the total mortality risk during the lactation.

Mean mortality risk for the first 100 days of the lactation was 2.5 % in the present study. Only a few authors have reported cow mortality risk or rates at the herd level. Faye and Perochon (1995) found annual mortality rates ranging from 0 to 0.042 among 47 dairy cattle herds in Brittany. Karuppanan and others (1997) studied nine Californian dairy cattle herds and found mortality rates from 0.008 to 0.064 per cow year. Esslemont and Kossaibati (1997) found a mean annual mortality rate of 0.016 among 50 dairy cattle herds in England. Gardner and others (1990) studied cow mortality in 43 Californian dairy cattle herds and found a median mortality rate per cow year of 0.022. The number of herds included in these studies is much lower than in our study, but nevertheless, both the average measures and the range of mortalities are of the same order. The maximum mortality risk among the herds in our study of 30.4 % was very high. Mortality risks this high were seldom (illustrated by the fact that the 99th percentile is 10.7).

None of the significant interactions identified were considered biologically relevant, as the predicted mortality was only to a very limited degree affected by including the interactions in the model.

We found a relatively low mortality risk in organic herds compared to conventional herds and a low mortality risk in herds pasture grazed during the summer. According to Danish legislation cows from organic herds must have exercise on a daily basis, all year round, even if they are housed in tie stall barns (Anon., 2000). Gustafson (1993) concluded that health in general was significantly influenced by exercise, reducing the frequency of veterinary treatment. Alban and Agger (1996) concluded that grazing is associated with better health. We have concluded that the mortality risk is reduced also.

Danish dairy production has undergone considerable structural changes during the last decade with creation of larger, but fewer herds (Anon., 2002b). Herds have increased in size by purchasing cows from dairy units going out of business. We found a high proportion of purchased cows to be a risk factor for cow mortality at the herd level. Unsuccessful adaptation to a new environment, physiological stress during entry into the new herd (Thrusfield, 1995, Radostits, 2001) or the exposure to previously unencountered infectious agents (Mota, 1986) may render purchased cows more susceptible to death. We did not have any information on the time of purchase in relation to calving or death. Therefore, we were not able to distinguish e.g. between cows purchased as calves and cows purchased a few weeks before calving. Further research is needed in this field. A high culling rate combined with an insufficient availability of replacement heifers may also necessitate purchase of many cows or heifers from other herds. In this situation problems within the herd (causing a high culling rate) might be the reason behind a high proportion of purchased cows. It is likely that such problems may also partly be responsible for the increased mortality risk seen in herds with a high proportion of purchased cows.

As in this present study, Smith and others (2000) found increasing mortality rates with increasing herd size among dairy cattle herds in the eastern part of the United States. However, no significant relation between percentage of dead cows and herd size was found in Canadian herds (Batra and others, 1971). In many cases the individual cow receives less attention in large herds (King, 1981, Dohoo and others, 1984, Nørgaard and others, 1999).

We found deep litter housing to be associated with a relatively low mortality risk. When comparing housing systems, free stall barns with deep litter constitute the least traumatic environment for the cow. The restrictions on movements are minimal. Several studies have shown that cows housed in free stall barns with deep litter have few lesions of the legs and claws compared to other housing systems (Webster, 2001, Livesey and others, 2002, Webster, 2002). As locomotor disorders is the most frequent primary reason for death or euthanasia among Danish dairy cows (Thomsen and others, 2004) this might be part of the explanation of the lower mortality seen in free stall barns with deep litter.

In the present study we found a decrease in mortality risk with increasing milk production. Smith and others (2000) also found a decrease in mortality rate with increasing production level among dairy cattle herds in the eastern part of the United States, whereas Batra and others (1971) found no significant relation between percentage of dead cows and herd production level in Canada. Bascom and Young (1998) found no significant relation between death as a culling reason and milk production. The relationship between mortality, milk yield and somatic cell count could be explained by general management factors. The influence of management style on production, disease and culling has been described by several authors (King, 1981, Dohoo and others, 1984, Bigras-Poulin and others, 1985a, Bigras-Poulin and others, 1985b, Carley and Fletcher, 1986, Keown, 1988, Faye, 1991, Pecsok and others, 1991, Beaudeau and others, 1996, Sargeant and others, 1997, Barkema and others, 1999, Kirkebæk and others, 2003). A high level of management is needed to achieve a high milk yield and a low somatic cell count (Pecsok and others, 1991, Sargeant and others, 1997, Barkema and others, 1999, Kirkebæk and others, 2003). We find that good management in many cases also might be part of the explanation behind low cow mortality.

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7. Validation of a protocol for clinical examination of dairy cows

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Submitted

Abstract

In 2004 five veterinarians examined 283 dairy cows from four Danish dairy herds and assigned scores for the clinical signs lameness, body condition, hock lesions, other cutaneous lesions, vaginal discharge, skin condition and general condition to each cow using a clinical protocol. We evaluated the inter-observer agreement using a Bayesian threshold model and the intra-observer agreement using kappa statistics. We chose two different cut-offs between the ordinal scores for classifying cows as healthy or diseased, and we compared the ability of the observers to discriminate between healthy and diseased cows for the two cut-offs.

We concluded that the clinical protocol was easy to use (not costly nor time-consuming). Even with no formal training of the observers we considered both intra- and inter-observer agreement acceptable. Kappa values for intra-observer agreement were in the range 0.40 to 0.70 and sensitivity and specificity for inter-observer agreement were in the range 0.66 to 0.99 and 0.47 to 0.98, respectively. We therefore found the protocol suitable for use both in research and in clinical practice.

Key words: Inter-observer agreement; intra-observer agreement; Bayesian threshold model; Kappa; dairy cows.

1. Introduction

Clinical examinations are used for many purposes in clinical practice and in research. In veterinary practice the outcome of the clinical examination serve as basis for important decisions like diagnosis, prognosis and treatment of animals. In research projects clinical examinations are also used extensively (e.g. Larsen et al., 2001, Steen, 2001, Klaas et al., 2003, Klaas et al., 2004, Rohn et al., 2004). Therefore, it is imperative that the observations are 'reliable'. The importance of reliable clinical observations has been stressed in humans (Mackenzie and Charlson, 1986, Wright and Feinstein, 1992) and in veterinary medicine (Smith, 1995). It has been stated that bias will always be present in biomedical research and that bias is accepted provided researchers do their best to diminish it or as a last resort to admit its presence (Horton, 2000). Bias may be inevitable, but if it is discussed (and possibly quantified) it is possible to take the effect of the bias into account, when decisions are taken on the basis of clinical examinations.

The purpose of this study was to assess reproducibility and repeatability for a clinical protocol that has been used for a large study of dairy cows with generally lowered health and production (commonly termed loser cows) in Danish dairy cattle herds (The Loser Cow Project). Based on clinical examinations of approximately 15,000 cows from 40 herds the objectives of that project were to estimate the prevalence of loser cows, evaluate risk factors for the condition and develop strategies for the prevention and handling of loser cows. A loser cow was defined based on clinical signs and the effect of these signs on survival, morbidity and production traits were studied.

For continuous as well as ordinal responses the choice of cut-offs for categorising an individual as healthy or diseased have important implications. For example in The Loser Cow Project left-skewed distributions were seen for most clinical signs, meaning that relatively few cows were observed with severe clinical signs while there were many cows with no signs or only mild signs. Changing the cut-off may therefore have a large impact on the total number of cows classified as either healthy or diseased and, hence, on the estimation of potential risk factors. Even more important, because the distances between the disease categories often are not equidistant (i.e. it might be more difficult to discriminate between mild signs than it is to discriminate between more severe signs), it is conceivable that the ability of veterinary clinicians to discriminate among diseased and healthy cows may be different for different cut-offs. We wanted to evaluate the ability to generalize the results from the Loser Cow Project and evaluate the usage of the protocol in clinical practice and in research. Therefore, we wanted to evaluate the clinical protocol among the potential users.

Cohen's kappa has been widely used to assess observer agreement (e.g. Brothwell et al., 2003, Molander et al., 2003, Venhola et al., 2003, Petersen et al., 2004, Stavem et al., 2004). However, the use of kappa has several disadvantages. Kappa depends not only on the agreement between the observers, but is also affected by the distribution of observations within the m x n contingency matrix (the prevalence of the clinical trait observed and the presence of bias between observers) (Byrt et al., 1993, Lantz and Nebenzahl, 1996, Dohoo et al., 2003). Additionally, kappa allows only simultaneous comparison of two observers (Woodward, 1999).

In the present study, we have quantified the simultaneous inter-observer agreement among 5 veterinarians using a hierarchical Bayesian threshold model and the latent class approach for two different cut-offs. In its basic model-formulation a continuous variable represents the strength of the disease, e.g. the severity of the condition, and another variable, the threshold parameter, represents the classification by the individual observer into the diseased and the healthy category (see Baadsgaard and Jørgensen (2005) for a more thorough description of the model). The parameterisation in this model allows us to study the effect of using different cut-offs between the ordinal scores on the ability of the observers to discriminate between healthy and diseased cows. Although we have applied up to 5 scores for some of the clinical signs we have restricted ourselves to working with only binary disease states and hence binary recordings, when analysing the data. Additionally, because our study design enabled us to assess intra-observer agreement for a subset of the data, we supplemented our results with the kappa-coefficient for the intra-observer agreement for two veterinarians. We were not able to use the Bayesian threshold model for this subset of the data because the number of observations was too small.

2. Materials

2.1 The protocol and the choice of cut-offs
The clinical protocol for this study is identical to the one used for The Loser Cow Project. Clinical scores were assigned to the cows using the protocol in Table 1. The scores for lameness is from Sprecher et al. (1997) and the body condition scores are modified after Ferguson et al. (1994).

For the analysis we chose two different cut-offs between healthy and diseased cows. The difference between the cut-offs is described in Table 2. We decided to use two different cut-offs between the categories 'healthy' and 'diseased' for three clinical signs: lameness, hock lesions and other cutaneous lesions. These three clinical signs had a relatively large apparent prevalence and were considered important in relation to loser cows.

2.2 The observers
The five observers were all veterinarians with experience from clinical practice (11, 6, 28, 4 and 2 years, respectively). Three of the observers (1, 2, and 5) were researchers at the Danish Institute of Agricultural Sciences and two (3 and 4) were bovine practitioners. Observer 2 (the first author of this paper) developed the clinical protocol and had used it in The Loser Cow Project for one year.

Table 1. Description of the clinical protocol used in a study of inter- and intra-observer agreement among Danish clinicians regarding clinical examination of dairy cows.

Clinical sign	Scores
Lameness (from Sprecher et al., 1997)	1: Normal: The cow stands and walks with a level-back posture. Her gait is normal. 2: Mildly lame: The cow stands with a level-back posture but develops an arched-back posture while walking. Her gait remains normal. 3: Moderately lame: An arched-back posture is evident both while standing and walking. Her gait is affected and is best described as short-striding with one or more limbs. 4: Lame: An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favors one or more limbs/feet. 5: Severely lame: The cow additionally demonstrates an inability or extreme reluctance to bear weight on one or more of her limbs/feet.
Body condition score (BCS) (modified after Ferguson et al., 1994)	1: Fat: BCS >= 4. 2: Normal: 2.25<=BCS<=3.75. 3: Thin: 1.5<=BCS<=2. 4: Emaciated: BCS<=1.25
Hock lesions (only the most severe lesion found is scored)	1: No hock lesions: no contusions or abscesses, no hair loss, no thickening of the skin. 2: Hair loss and/or slight thickening of the skin and/or wounds <= 2 cm in diameter. 3: Hyperkeratosis and swelling of the skin and/or fluid filled bursae and/or larger wounds (>2 cm in diameter). 4: Larger swellings with hyperkeratosis and fluid filled bursae and/or abscesses. Wounds may be present. Suppurative lesions and lesions affecting the hock joint and/or bones may be present.
Other cutaneous lesions (hips, neck, ribs, legs, back or other parts of the body besides hocks) (only the most severe lesion found is scored)	1: No lesions: no contusions or abscesses, no hair loss, no thickening of the skin. 2: Hair loss and/or slight thickening of the skin and/or wounds <= 2 cm in diameter. 3: Hyperkeratosis and swelling of the skin and/or fluid filled bursae and/or larger wounds (>2 cm in diameter). 4: Larger swellings with hyperkeratosis and fluid filled bursae and/or abscesses. Wounds may be present. Suppurative lesions and lesions affecting joints and/or bones may be present.
Vaginal discharge	1: No vaginal discharge. 2: Vaginal discharge seen from the vagina and/or on the tail and/or perineum.
Skin condition	1: Skin shiny, no or only a little dust on the back. 2: Skin dull, dust on the back of the cow. 3: Skin very dull, much dust on the back, a general impression of a cow not cleaning herself.
General condition	1: Undisturbed general condition. 2: Slightly disturbed general condition, slight dullness, slightly depressed 3: Disturbed general condition, very dull, depressed, grinding of teeth might occur.

The other observers had not used the protocol before. The observers received the description of the protocol (Table 1) a few days before the experiment. At the first day of the experiment, observer 2 gave a short introduction to the protocol prior to examination of the first cow. Henceforth, the observers assigned the clinical scores independently.

Table 2. Categorisation of scores as 'healthy' or 'diseased' in a study of inter- and intra-observer agreement on clinical examinations of Danish dairy cows. Cut-offs are explained in the text.

		Healthy	Diseased
Lameness	1. cut-off	1	2, 3, 4, 5
	2. cut-off	1, 2	3, 4, 5
Hock lesions	1. cut-off	1	2, 3, 4
	2. cut-off	1, 2	3, 4
Other cutaneous lesions	1. cut-off	1	2, 3, 4
	2. cut-off	1, 2	3, 4
Vaginal discharge		1	2
Skin condition		1	2, 3
General condition		1	2, 3

2.3 The herds

We selected four commercial dairy herds for the experiment by convenience sampling (geography, co-operative farmer, free stall barns with cubicles and catch crates in the barn). The herds had 116, 104, 103 and 197 cows, respectively. All the cows were Danish Holstein. In all herds the cows were locked in the catch crates prior to the examination and 81, 68, 61 and 73 cows, respectively, were selected randomly for examination in each herd. The number of cows examined in each herd were chosen so that the total examination in each herd did not exceed three hours. Each herd was visited twice within a few days. At the second visit to each herd, the cows that were scored during the first visit were identified and scored again. Three of the herds were visited twice on two successive days and the last herd was visited twice 8 days apart. All visits took place in October and November 2004. During the first visit observers 1, 2, and 4 scored the cows. During the second visit observers 1, 2, 3, and 5 scored the cows. The design allowed us to calculate both intra- and inter-observer agreement (repeatability and reproducibility) (Toma et al., 1999). Intra-observer agreement (repeatability) was calculated for observers 1 and 2 and inter-observer agreement (reproducibility) was calculated for all observers. Only observations from the first visit to each herd for observers 1 and 2 were used when we calculated inter-observer agreement.

2.4 The examination

The observers first examined the individual cow when she was locked in the catch crate and, afterwards, as she walked 10-30 meters on the slatted floor. All observers simultaneously scored the cow and they were neither allowed to discuss nor compare their findings. The examination of each cow took 1-2 minutes, and the total examination in each herd lasted approximately three hours.

3. The statistical model

3.1 The threshold model

We estimated the true unobserved disease state for the clinical signs lameness, hock lesions and other cutaneous lesions in a Bayesian latent class model as in Baadsgaard and Jørgensen (2005). The probability of having a positive test outcome conditioning on a positive true disease state for clinical sign s; s=1,2,3 (lameness, hock lesions and other cutaneous lesions) and for veterinarian v;

v=1,2,…,5 in the model was denoted Se_{sv}, and the probability of having a negative test outcome conditioning on a negative true disease state was denoted Sp_{sv}.

The main components of the threshold model are illustrated in Figure 1. An underlying continuous latent variable was created to represent the strength (i.e. the severity) of the clinical signs. Healthy animals have low values of this latent variable (solid line), and diseased animals have higher values (dashed line). A veterinarian classifies animals according to a threshold value τ_{sv}, that is, animals with values below the threshold are classified as *healthy* (non-diseased) and above they are classified as *diseased*. The difference between the mean of the *healthy* and the *diseased* population is denoted Δ_{sv} . Thus the characteristics of an observer (a veterinarian) can be summarized into two parameters: the difference between the population means (Δ_{sv}) and the threshold value (τ_{sv}). These two values can easily be transformed into the corresponding Se_{sv} and Sp_{sv} values. Because we are working in a Bayesian context we need to assign priors to the parameters in the model. Standard non-informative priors were applied as in Baadsgaard and Jørgensen (2005). The priors were updated after entering the data and the posterior population means and variances of the population means for Δ_{sv} and τ_{sv}; i.e. $\mu_{\Delta_{sv}}$ and $\sigma_{\Delta_{sv}}$ and $\mu_{\tau_{sv}}$ and $\sigma_{\tau_{sv}}$, respectively, were estimated. The analysis was performed using the McMC-approach (Brooks, 1998) via the WinBugs-program (Spiegelhalter et al., 2000). The individual estimates of Se and Sp were displayed using ROC-curves.

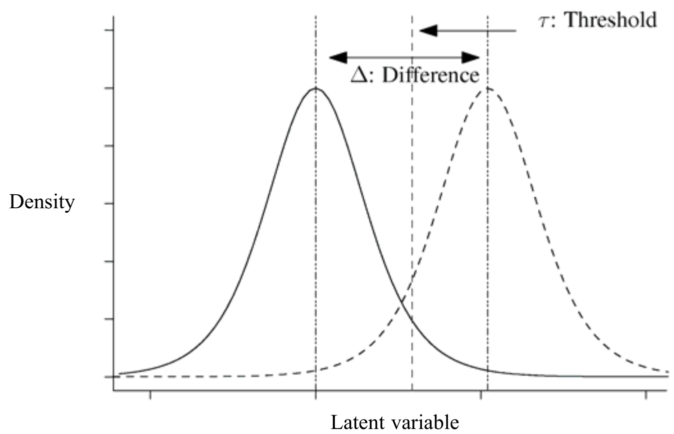

Figure 1. Graphical representation of the threshold model. Δ is the difference between the diseased (dashed curve) and the healthy (solid curve) cows and τ is the observer dependent threshold value.

3.2 Intra-observer agreement using the kappa coefficient
Intra-observer agreement was calculated for observers 1 and 2. We calculated prevalence-adjusted, bias-adjusted kappa (PABAK), bias index (BI), prevalence index (PI), observed agreement (P_o), positive agreement (P_{pos}) and negative agreement (P_{neg}) as described by Byrt et al. (1993).

4. Results

4.1 The observed distribution of test outcomes
The observed distribution of positive test outcomes for the 1. and the 2. cut-off are displayed in Table 3. Test distributions for lameness and hock lesions changed considerably when the cut-off

was changed. When the 1. cut-off was used the positive test-outcomes predominate. The number of cows with complete agreement on the presence of either lameness or hock lesions was 112 and 145, respectively. For the 2. cut-off the number of cows with complete agreement on the presence was only 36 and 20, respectively. Complete agreement on the absence of these signs for the 1. cut-off was 20 and 8 cows, respectively, while, for the 2. cut-off the number of cows was 156 and 172, respectively. For other cutaneous lesions, the effect was different but still pronounced. The number of cows with complete agreement on the absence of cutaneous lesions was 85 and 207, respectively.

Table 3. Observed distribution of positive test outcomes for 1. and 2. cut-off (see text for explanation)

Number of positive test outcomes	Lameness		Hock lesions		Other cutaneous lesions	
	1. cut-off	2. cut-off	1. cut-off	2. cut-off	1. cut-off	2. cut-off
0	20	156	8	172	85	207
1	17	36	25	55	49	33
2	24	20	26	8	40	14
3	42	23	28	12	33	10
4	68	12	51	16	40	12
5	112	36	145	20	36	7

The number of cows with complete agreement on the presence of cutaneous lesions was 36 for the 1. cut-off and only 7 for the 2. cut-off. Generally, the number of positive test-outcomes less than 5 and greater than 0 (=cows where all veterinarians did not agree whether the cows should be classified as healthy or diseased) was larger for the 1. cut-off than for the 2. cut-off. Hence, the observed variability among the observers was less for the 2. cut-off than for the 1. cut-off.

4.2 The threshold model

4.2.1 Individual estimates

Individual estimates of Se_{sv} and Sp_{sv} are presented in Tables 4 and 5 and in the ROC-curves in Figures 2, 3 and 4. For lameness and hock lesions there was a general increase in the Sp and a decrease in the Se when using the 2. cut-off compared to the 1. cut-off. Generally, Se were higher than Sp for the 1. cut-off, while the opposite was the case for the 2. cut-off. For other cutaneous lesions the changes were similar, the effect on Sp being somewhat smaller, though.

When comparing the veterinarians (=observers) v=3 had the lowest AUC (area under the curve) for lameness and hock lesions for the 1. cut-off and for other cutaneous lesions for both cut-offs. Veterinarian v=5 had the lowest AUC for lameness and hock lesions for the 2. cut-off. Generally, veterinarians 3 and 5 had the lowest AUC. Veterinarian v=2 (the experienced observer) had the largest value of AUC for hock lesions for both cut-offs and for lameness for the 1. cut-off. Veterinarian v=1 had the largest value of AUC for lameness for the 2. cut-off and for the 1. cut-off for other cutaneous lesions.

4.2.2 Population estimates

The posterior median difference between the diseased and the healthy population was different for the 1. and the 2. cut-off (Tables 4 and 5). Generally, the difference was larger for the 2. cut-off. The median difference was 4.23, 4.21 and 3.47 for lameness, hock lesions and other cutaneous lesions for the 1. cut-off. For the 2. cut-off, the median difference was 4.45 , 4.80 and 4.29, respectively.

Compared to the 1. cut-off the standard deviations for the 2. cut-off were smaller for the median difference for lameness and hock lesions. For other cutaneous lesions, the standard deviation was somewhat larger for the 2. cut-off.

Table 4. Medians and 95% credibility intervals for the clinical accuracy for three different clinical signs in four Danish dairy cattle herds for the 1. cut-off in the clinical protocol (see text for explanation). The results were based on 5001-15000 iterations from the Gibbs sampler. CI: Credibility interval; SD: Standard deviation; Pop. est. : Population estimate

	Lameness		Hock Lesions		Other cutaneous lesions	
	Median	95% CI	Median	95% CI	Median	95% CI
Pop. est. of precision	4.23	1.73-6.67	4.21	1.78-6.54	3.47	2.45-4.64
SD of precision	2.78	1.16-4.83	2.57	1.05-4.76	0.77	0.09-2.68
Pop. est. of threshold	1.02	0.18-2.25	0.77	0.10-2.05	2.36	1.13-3.85
SD of threshold	0.89	0.39-2.59	0.91	0.40-2.86	1.11	0.50-3.10
Se_1	0.86	0.79-0.90	0.95	0.91-0.98	0.65	0.56-0.74
Se_2	0.99	0.98-1.00	0.99	0.98-1.00	0.73	0.64-0.81
Se_3	0.75	0.68-0.81	0.88	0.83-0.93	0.53	0.44-0.62
Se_4	0.99	0.96-1.00	0.99	0.97-0.99	0.94	0.89-0.97
Se_5	0.78	0.71-0.84	0.82	0.76-0.88	0.71	0.62-0.80
Sp_1	0.78	0.68-0.87	0.83	0.71-0.91	0.96	0.92-0.99
Sp_2	0.47	0.34-0.60	0.74	0.62-0.85	0.89	0.82-0.94
Sp_3	0.76	0.65-0.85	0.53	0.40-0.64	0.93	0.88-0.97
Sp_4	0.81	0.67-0.92	0.48	0.35-0.60	0.75	0.66-0.84
Sp_5	0.77	0.66-0.87	0.72	0.61-0.81	0.94	0.89-0.98

Table 5. Medians and 95% credibility intervals for the clinical accuracy for three different clinical signs in four Danish dairy cattle herds for the 2. cut-off in the clinical protocol (see text for explanation). The results were based on 5001-15000 iterations from the Gibbs sampler. CI: Credibility interval; SD: Standard deviation; Pop. est. : Population estimate

	Lameness		Hock lesions		Other cutaneous lesions	
	Median	95% CI	Median	95% CI	Median	95% CI
Pop. est. of precision	4.45	3.08-5.92	4.80	3.72-5.98	4.29	3.16-5.53
SD of precision	1.04	0.23-3.35	0.65	0.02-2.85	0.81	0.07-3.11
Pop. Est. of threshold	3.18	1.97-4.63	3.03	1.73-4.43	3.75	2.70-5.01
SD of threshold	0.97	0.30-3.05	1.10	0.50-3.04	0.77	0.18-2.60
Se_1	0.76	0.65-0.86	0.82	0.70-0.91	0.60	0.45-0.75
Se_2	0.73	0.63-0.83	0.90	0.79-0.98	0.44	0.30-0.60
Se_3	0.66	0.56-0.77	0.94	0.85-0.98	0.65	0.49-0.79
Se_4	0.90	0.82-0.96	0.87	0.77-0.94	0.82	0.66-0.94
Se_5	0.76	0.66-0.86	0.58	0.44-0.72	0.57	0.42-0.71
Sp_1	0.98	0.95-0.99	0.97	0.94-0.98	0.98	0.97-0.99
Sp_2	0.97	0.93-0.99	0.95	0.92-0.97	0.98	0.97-0.99
Sp_3	0.97	0.93-0.99	0.86	0.80-0.90	0.95	0.92-0.98
Sp_4	0.94	0.89-0.97	0.95	0.91-0.97	0.97	0.94-0.99
Sp_5	0.90	0.85-0.94	0.98	0.96-0.99	0.98	0.96-0.99

There was a simultaneous increase in the median population estimates of the thresholds going from the 1. to the 2. cut-off. The posterior medians were 1.02, 0.77 and 2.36 for the 1. cut-off. For the 2. cut-off the thresholds were 3.18, 3.03 and 3.75, respectively. The standard deviations of the population estimates of the thresholds showed only a moderate increase from the 1. to the 2. cut-off.

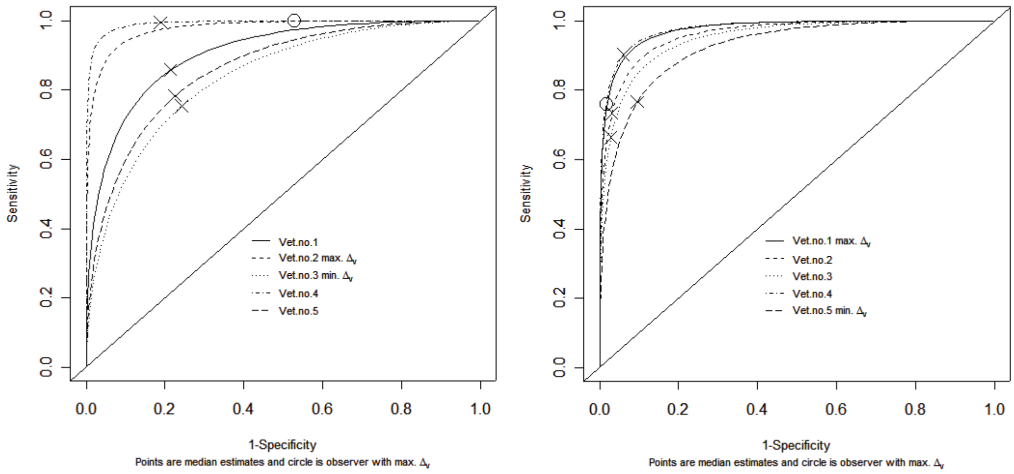

Figure 2. ROC-curves for the 1. (left) and the 2. cut-off (right) in the clinical protocol for lameness.

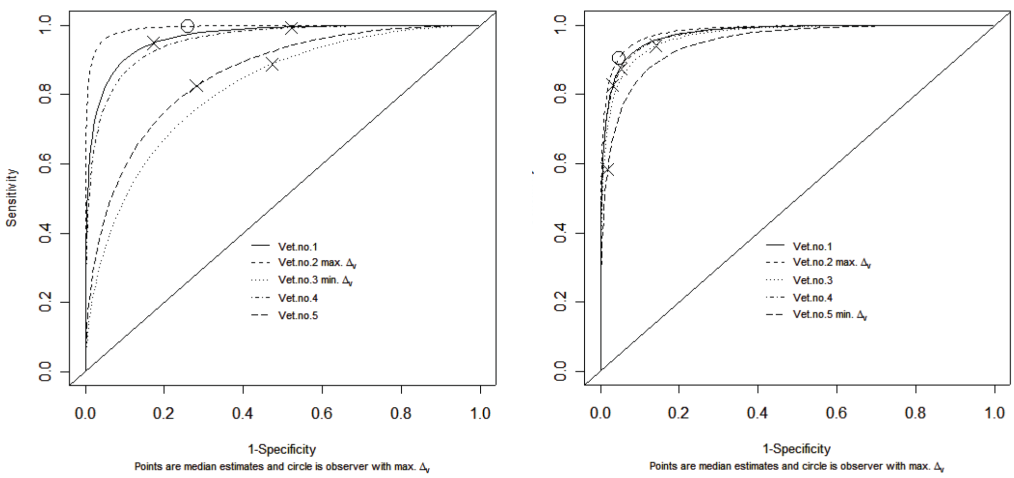

Figure 3. ROC-curves for the 1. (left) and the 2. cut-off (right) in the clinical protocol for hock lesions.

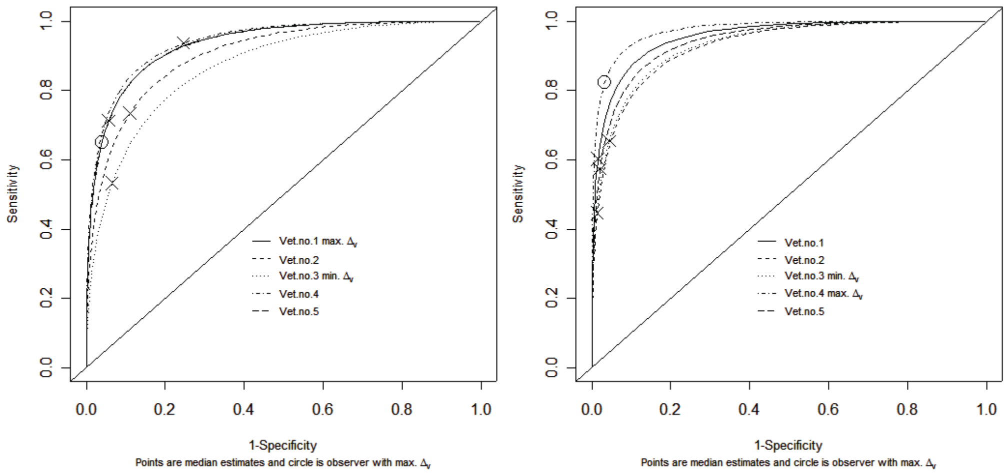

Figure 4. ROC-curves for the 1. (left) and the 2. cut-off (right) in the clinical protocol for other cutaneous lesions.

4.3 Intra-observer agreement using the kappa coefficient

Table 6 presents results on intra-observer agreement for observers 1 and 2. Only results for the clinical traits lameness, hock lesions, other cutaneous lesions, vaginal discharge and skin condition are shown.

Table 6. Intra-observer agreement for observers 1 and 2 for two scorings of the same cows in four Danish dairy herds. The difference between 1. and 2. cut-off is explained in the text.

Clinical sign	Cut -off	Observer	Kappa	PABAK	BI	PI	P_o	P_{pos}	P_{neg}
Lameness	1.	1	0.51	0.60	-0.05	0.43	0.80	0.86	0.65
	1.	2	0.68	0.85	0.03	0.74	0.93	0.96	0.72
	2.	1	0.65	0.77	0.04	-0.57	0.88	0.73	0.93
	2.	2	0.71	0.80	0.02	-0.53	0.90	0.78	0.93
Hock lesion	1.	1	0.60	0.69	0.03	0.46	0.84	0.89	0.71
	1.	2	0.70	0.80	0.01	0.60	0.90	0.94	0.76
	2.	1	0.66	0.82	0.04	-0.69	0.91	0.71	0.95
	2.	2	0.70	0.82	0.03	-0.63	0.91	0.75	0.94
Other cutaneous lesions	1.	1	0.53	0.55	-0.05	-0.25	0.78	0.70	0.82
	1.	2	0.69	0.69	-0.01	-0.13	0.85	0.82	0.87
	2.	1	0.67	0.88	0.01	-0.78	0.94	0.71	0.97
	2.	2	0.57	0.88	0.01	-0.84	0.94	0.60	0.97
Vaginal discharge		1	0.52	0.95	-0.01	-0.95	0.97	0.53	0.99
		2	0.66	0.98	0.00	-0.97	0.99	0.67	0.99
Skin condition		1	0.39	0.39	-0.09	0.09	0.69	0.72	0.66
		2	0.48	0.51	-0.08	0.26	0.76	0.81	0.67

PABAK: Prevalence-adjusted bias-adjusted kappa; BI: Bias index; PI: Prevalence index; P_o: Observed agreement; P_{pos}: Positive agreement; P_{neg}: Negative agreement.

We considered kappa values for body condition score and general condition highly biased because of a highly skewed distribution of agreements (majority of agreements in the same cell of a 2 x 2 table due to a very low prevalence of the clinical sign). This will result in a very low kappa-value regardless of a high proportion of agreement among observers (Lantz and Nebenzahl, 1996). For body condition score and general condition we found kappa near 0, PABAK near 1, P_o near 1 and PI near –1.

5. Discussion

In this study we have shown that there were considerable differences in the distributions of the positive test outcomes (the number of veterinarians classifying a cow as healthy and diseased, respectively) using the 1. and the 2. cut-off for 3 clinical signs in Danish dairy cows. Consequently, we obtained different results for Se_{sv} and Sp_{sv} when we changed the cut-off.

For lameness and hock lesions there was a clear change in Se and Sp with an increase in Sp and a decrease in Se when shifting from the 1. cut-off to the 2. cut-off. For example, for veterinarian v=2 Se and Sp for lameness changed from 0.99 and 0.47 to 0.73 and 0.97. Similar changes were seen for the other veterinarians. Although we on average only obtained a slight more clear distinction between the diseased and the healthy cows using the 2. cut-off, the veterinarians were more reluctant to classify the cows with clinical signs as diseased as illustrated with the concomitant increase in the threshold values.

Generally, as illustrated both in the observed distribution of positive test outcomes and in the ROC-curves (Table 3 and Figures 2, 3 and 4) the variability among the veterinarians was much smaller for the 2. cut-off for lameness and hock lesions. For other cutaneous lesions the decrease in the variability was less pronounced.

Very few studies have addressed observer agreement using latent class techniques and the threshold model. Compared to the results in Baadsgaard and Jørgensen (2005) we concluded that the agreement among the observers in the present study was acceptable for all 3 signs. In the ROC-curves Δ_{sv} is fixed and the curves show the potential improvement that can be achieved by varying the threshold. In general, the optimal choice of threshold depends on the purpose of a specific study. If a high Se is considered more important than a high Sp a lower threshold may be optimal and if a high Sp is considered more important than a high Se a higher threshold may be optimal. The difference between Se and Sp using the two cut-offs may be used strategically. If one for some reason wants a high Se and can accept a low Sp, then the 1. cut-off should be used. And the 2. cut-off should be used if a low Se and a high Sp are preferred.

The observers (excluding observer 2) had no experience with the protocol. Therefore, it is not surprising that observer 2, who constructed the protocol and who had used the protocol intensively, generally obtained high values of Δ_{sv}. It is conceivable that training would decrease the proportion of disagreement and increase sensitivity and specificity. The present situation may therefore be considered as a 'worst case scenario', albeit a realistic scenario, for the agreement in a small sample of Danish dairy veterinarians.

One important question remains to be answered regarding the interpretation of our results: To what extent does the change in the number of truly diseased cows affect Δ_{sv}? Our results could indicate that highly skewed distributions of the observed test outcomes may predispose to high values of Δ_{sv}, which also makes sense in the way that a skewed distribution indicates acceptable discrimination in contrast to a more flat distribution. However, a bimodal distribution would always be preferred because it contains evidence on both the diseased and the healthy cows.

The kappa values found for intra-observer agreement were in the range 0.40 to 0.70, which is traditionally regarded as moderate to substantial agreement (Landis and Koch, 1977, Dohoo et al., 2003) or good agreement (Fleiss, 1981), respectively. In general bias indexes (BI, Table 6) were close to 0. This indicates equal marginal proportions and no bias (Byrt et al., 1993). Prevalence indexes (PI, Table 6) on the other hand were generally closer to +1 or –1. This indicates that kappa is biased (too small) due to a prevalence of the clinical sign under observation differing from 50 % (Byrt et al., 1993). Kappa and PABAK values were generally higher using the 2. cut-off.

It has been argued that the use of binary data in many statistical models in biomedicine oversimplifies the clinical reality (Feinstein, 1990), and so far most studies on diagnostic test evaluations have been on binary test outcomes and within the framework of Se and Sp. A natural extension of the threshold model would be to include information on e.g. 3 categories of clinical scores i.e. mild, moderate or severe lameness or hock lesions. Such a strategy would obviate the need for dichotomising the data and take further advantage of the information in the data.

The two scorings of each cow were in most cases one day apart. This short time between observations decreased the possibility that any of the conditions scored could change from the first to the second scoring. On the other hand, the short time between scorings increased the possibility that one or more of the observers could remember a specific cow and her scores from the previous day. We concluded that this was not likely due to the relatively high number of cows scored each day.

Vaginal discharge and skin condition may change in a few minutes or hours. Vaginal discharge may only be visible when the cow is lying down and the cow may clean herself and change the score for skin condition from '2' to '1' in a matter of minutes. The rest of the clinical signs scored normally do not change overnight. Scoring of the skin condition may be biased by the colour of the cow. All cows in the experiment were Danish Holstein, but the distribution of black and white patches naturally varied. We noted that dust was more easily seen on cows that were predominantly black. Thus, cows that were predominantly white were systematically assigned a lower score for skin condition than predominantly black cows.

Besides different thresholds for grouping the observed clinical signs into the different categories of the protocol, disagreement between observers may also originate from simply overlooking the presence of a clinical sign. This bias may be reduced by providing optimal conditions for observation (time, light, space etc.) (Baadsgaard and Enevoldsen, 1997).

To minimize bias due to observer fatigue the examinations lasted no longer than three hours per day. The material was too small for formal testing, but nevertheless there was a tendency for lower intra- and inter-observer agreement for observations made during the second half of the herd visits (data not shown).

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8. Loser Cows in Danish Dairy Herds: Definition, Prevalence and Consequences

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Submitted

Interpretive summary

Loser Cows in Danish Dairy Herds: Definition, Prevalence and Consequences, *by Thomsen et al.*

A loser cow is a new clinical entity. We defined a loser cow on the basis of a clinical examination of the cow. Scores for seven clinical signs were converted into a loser cow score. Cows with a loser cow score of 8 or more were classified as loser cows. The overall prevalence of loser cows in a random sample of Danish dairy herds was 3.24 %.

The loser cow state has significant negative consequences both in relation to animal welfare and financially for the farmer.

Abstract

A loser cow is a new clinical entity. We defined a loser cow on the basis of a clinical examination of the cow. A total of 15,151 cows from 39 randomly selected, large Danish dairy herds with loose-housing systems were examined using a clinical protocol. Scores for the clinical signs lameness, body condition, hock lesions, other cutaneous lesions, vaginal discharge, skin condition and general condition were converted into a loser cow score. Cows with a loser cow score of 8 or more were classified as loser cows. The overall prevalence of loser cows was 3.24 %.

The consequences of the loser cow state on milk production, mortality, morbidity, culling and workload for the farmer was evaluated using data from herd visits and from the Danish Cattle Database. It was concluded that the loser cow state has significant negative consequences for both the farmer and the cow.

A simplified version of the loser cow score was evaluated and is recommended for future research and use in practice.

Key words: loser cow, clinical examination, score, Danish dairy herds

Introduction

Danish dairy production has undergone considerable structural changes during the last decade with creation of larger, but fewer herds. From 1994 to 2004 the number of dairy herds has decreased from approximately 16,000 to 6600 and, at the same time, the average number of cows per herd has doubled to 90 cows per herd in 2004. The percentage of dairy farms with more than 100 cows has increased from approximately 2.5 % in 1991 to 22 % in 2002. Since the mid-nineties a large number of new cattle houses have been built. More than 70 % of the Danish dairy cattle population are now being housed in loose-housing systems, many of which have been built during the last few years. New technique used for milking (automatic milking systems), feeding and surveillance has been introduced. At the same time, the average milk yield per cow has increased and the number of man hours per cow has decreased (Barrett, 2004). Mortality among Danish dairy cows has increased from approximately 2 % in 1990 to 4 % in 2001 (Thomsen et al., 2004).

During the last few years, many Danish dairy farmers have started complaining about a new group of cows, which we have chosen to term ‘loser cows’. A loser cow is for different reasons not able ‘to keep up with’ the rest of the cows in the herd. Farmers typically complain about increased morbidity and mortality, decreased milk production, decreased animal welfare and extra workload. A loser cow has until now not been characterised scientifically, and hence no studies have been performed on the occurrence, risk factors for, and effects of loser cows. Our objectives were therefore to establish a scientific definition of a loser cow based on a clinical examination of the cow, evaluate the relation between the new ‘diagnosis’ loser cow and well-known clinical entities, estimate the prevalence of loser cows in Danish dairy herds with loose-housing systems and evaluate the consequences of loser cows on milk production, mortality, morbidity, culling and extra workload for the farmer. Our hypothesis was that a loser cow could be identified on the basis of a clinical examination. In addition it is hypothesised that milk production, mortality, culling, morbidity and workload for the farmer are affected by being a loser cow.

Materials and methods

Clinical Protocol

We developed a clinical protocol for the examination of dairy cows (Table 1). The choice of the clinical signs included in the protocol was based on a practical consideration. Basically, all relevant clinical signs that could be assessed from a distance of 1-2 meters without any fixation of the cow were included. The scores for lameness is from Sprecher et al. (1997) and the body condition scores are modified after Ferguson et al. (1994). The remaining scores were developed for this study. The clinical protocol has been evaluated regarding inter- and intra-observer agreement by Thomsen and Baadsgaard (2005).

Selection of Herds

In August 2003, we extracted a list from the Danish Cattle Database of all herds that met the following criteria: Loose-housing system, more than 100 cows during the period 1st October 2001 to 30th September 2002, more than 95 % of the cow days in the herd constituted by Danish Holstein, herd participating in milk recording (member of a Milk Control Association) and cows being conformation scored by breeding inspectors from a cattle breeding organisation. This list included 274 Danish dairy cattle herds. The list was further reduced by only including herds with an acceptable level of disease recordings. The level of disease recording was judged unacceptable for herds with less than 0.1 cases of mastitis recorded per cow per year and for herds consulting a veterinarian with disease recordings in less than 75 % of the herds he/she attended. Furthermore, to keep transportation times at a reasonable level only herds in a distance from the Danish Institute of Agricultural Sciences, Foulum, of less than approximately 150 km were included. This was done on the basis of postal codes. This revised list included 172 herds. These herds were invited by mail to participate in the project. In the letter, it was specified that only herds where no expansions or major changes of the housing system etc. were planned during the following one and a half year could participate in the project. A total of 86 herds (= 50 %) responded to our letter. Among these, 53 were interested in participating in the project and 33 declined. Two of the herds that were interested in participating in the project were consulting a veterinary practice that did not answer calls during nights and weekends. Due to potential bias regarding disease recordings these herds were excluded.

Table 1. Description of the clinical protocol used in a study of loser cows in 39 Danish dairy cattle herds.

Clinical sign	Scores
Lameness (from Sprecher et al., 1997)	1: Normal: The cow stands and walks with a level-back posture. Her gait is normal. 2: Mildly lame: The cow stands with a level-back posture but develops an arched-back posture while walking. Her gait remains normal. 3: Moderately lame: An arched-back posture is evident both while standing and walking. Her gait is affected and is best described as short-striding with one or more limbs. 4: Lame: An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favours one or more limbs/feet. 5: Severely lame: The cow additionally demonstrates an inability or extreme reluctance to bear weight on one or more of her limbs/feet.
Body condition score (BCS) (modified after Ferguson et al., 1994)	1: Fat: BCS >= 4. 2: Normal: 2.25<=BCS<=3.75. 3: Thin: 1.5<=BCS<=2. 4: Emaciated: BCS<=1.25
Hock lesions (only the most severe lesion found is scored)	1: No hock lesions: no contusions or abscesses, no hair loss, no thickening of the skin. 2: Hair loss and/or slight thickening of the skin and/or wounds <= 2 cm in diameter. 3: Hyperkeratosis and swelling of the skin and/or fluid filled bursae and/or larger wounds (>2 cm in diameter). 4: Larger swellings with hyperkeratosis and fluid filled bursae and/or abscesses. Wounds may be present. Suppurative lesions and lesions affecting the hock joint and/or bones may be present.
Other cutaneous lesions (hips, neck, ribs, legs, back or other parts of the body besides hocks) (only the most severe lesion found is scored)	1: No lesions: no contusions or abscesses, no hair loss, no thickening of the skin. 2: Hair loss and/or slight thickening of the skin and/or wounds <= 2 cm in diameter. 3: Hyperkeratosis and swelling of the skin and/or fluid filled bursae and/or larger wounds (>2 cm in diameter). 4: Larger swellings with hyperkeratosis and fluid filled bursae and/or abscesses. Wounds may be present. Suppurative lesions and lesions affecting joints and/or bones may be present.
Vaginal discharge	1: No vaginal discharge. 2: Vaginal discharge seen from the vagina and/or on the tail and/or perineum.
Skin condition	1: Skin shiny, no or only a little dust on the back. 2: Skin dull, dust on the back of the cow. 3: Skin very dull, much dust on the back, a general impression of a cow not cleaning herself.
General condition	1: Undisturbed general condition. 2: Slightly disturbed general condition, slight dullness, slightly depressed 3: Disturbed general condition, very dull, depressed, grinding of teeth might occur.

Out of the remaining 51 herds 40 herds were selected for the project by random sampling.

During the project period, one herd wanted to leave the project after two of the three visits with clinical examination of the cows. Another herd installed an automatic milking system and changed the housing system just prior to the third visit. Only cows examined during the first two visits in these two herds were included in the dataset. One herd was not able to keep acceptable records regarding culling of cows. At the same time, this herd was the only herd where we were not able to examine all the cows. Approximately one third of the cows were breed by a bull. This made examination of these cows impossible. This herd was therefore excluded from the study. Thus, among the 39 herds included in the study, 37 were visited 3 times and 2 were visited twice.

Clinical Examination

All herds were visited three times (twice for two of the herds) with an interval of approximately 120 days during the period September 2003 to October 2004. The clinical experience of the observer (first author) includes 6 years as a bovine practitioner. Before the visit to the herd, an updated list with all the cows in the herd was obtained from the Danish Cattle Database. This list was used to make sure that almost all cows in the herd were examined. The observer continued the examination until at least 95 % of the cows (both lactating cows and dry cows) in the herd had been examined. In a few herds, the dry cows were housed in tie stall barns. These cows were not examined as it was not straightforward to evaluate lameness in these cows. The cows were not tied for the examination, but were examined as they walked around in the stable or on pasture. Lameness was scored after seeing the cow walking for at least approximately 15 meters. The examination of each cow took approximately 1 minute, and the total examination in each herd lasted approximately two to seven hours depending on herd size.

Database with Information on Individual Cows

Information about individual test day milk yields, recordings of disease treatments, dates for calving and culling, parity, pedigree and breeding values for milk production etc. on individual cows was obtained from the Danish Cattle Database. Every time a cow was culled during the project period (September 2003 to October 2004), the farmer recorded the date of culling, culling mode (death, euthanasia, slaughter or sale for dairy purposes), the reason for culling and his/her subjective opinion regarding the workload associated with this particular cow compared to an 'average' cow in the herd.

All the information about an individual cow was gathered in a database. The key to retrieve each individual record in the database was the Central Cattle Registration number of the individual cow. Some information was obtained from more than one source. When a cow e.g. died, the death was recorded both by the farmer and by the incineration plant and when a cow was slaughtered it was recorded both by the farmer and by the slaughter house. Consistency between this information was checked.

Calculation of Loser Cow Score

The results of the clinical examination were converted into a loser cow score. This conversion was based on an assessment of the relative importance of the deviation from the normal condition (represented by a perfectly normal, healthy cow) for each of the clinical signs observed. The deviation from the normal condition for each clinical sign were weighted both in relation to the degree of deviation from the normal condition regarding that particular sign and in relation to the other clinical signs. The normal condition and deviations from the normal condition that were considered of no or only minimal clinical importance were assigned the value '0'. To recognize the greater clinical importance of higher scores we used a geometrically progressive scale (powers of 2: 2^0, 2^1, 2^2 and 2^3) (Greenough and Vermunt, 1991; Leonard et al., 1996; Offer et al., 1997; Winckler and Willen, 2001). The conversion into points for the loser cow score is shown in Table 2. The loser cow score was defined as the sum of the points for each of the seven clinical signs. In this way, each cow observed was assigned a loser cow score ranging from 0 to 32. We wanted to classify cows as loser cows or non loser cows. In order to establish the distinction (threshold) between the two groups, we evaluated the magnitude of consequences on milk production, mortality, culling, morbidity and workload for the farmer for different definitions of a loser cow. This was done as described in the following section. We changed the definition of a loser cow by changing the minimum loser cow score that was needed for a cow to be classified as a loser cow (cut-off). This cut-off was changed in steps of one point from 4 to 10. In other words, first we defined all cows with 4 points or more as loser cows and estimated the consequences of being a loser cow compared to being a non loser cow. Then we did the same using 5 points as the cut-off and so on. The consequences of being a loser cow (the loser cow state) for different cut-offs were then indexed. The maximum value found for any consequence (e.g. the maximum hazard ratio for death or the maximum decrease of milk production) was assigned the index 100. All other values were indexed by dividing the numerical value found for different cut-offs by the maximum value found. This way we wanted to examine if there was a sudden change in the magnitude of the consequences of being a loser cow between any two cut-offs (e.g. a large change of the consequences when the threshold for being classified as a loser cow changed from 6 to 7 points). If such a change existed it would probably be a good choice for the final threshold for classifying cows as loser cows and non loser cows.

Table 2. Conversion of the clinical scores into points for a 'loser cow score' in a Danish study of loser cows. Points are shown as the raised numbers for each clinical score.

Lameness	1^0 2^1 3^2 4^4 5^8
Body condition score	1^0 2^0 3^4 4^8
Hock lesions	1^0 2^0 3^1 4^2
Other cutaneous lesions	1^0 2^0 3^1 4^2
Vaginal discharge	1^0 2^2
Skin condition	1^0 2^1 3^2
General condition	1^0 2^4 3^8

Consequences of the Loser Cow Score: Statistical Analysis

Our hypothesis was that milk production, mortality, culling, morbidity and workload for the farmer were affected by the loser cow score. We expected that the negative consequences for the cow and for the farmer would increase with increasing loser cow score. To evaluate this hypothesis, we examined the relation between the loser cow score and milk production, mortality, culling, diseases and workload. Only cows examined during the first of the three visits to each herd were included in the analysis (N=5105). This was done to ensure a relatively long follow-up period. The last visit in the first round of clinical examinations took place 2nd February 2004 and data regarding disease treatments, culling, milk production and mortality were collected until 1st October 2004. In this way, no cow had a follow-up period of less than 8 months.

All calculations were repeated with cut-offs between loser cows and non loser cows ranging from 4 to 10 points.

Milk production. The effect of the loser cow state on milk production was evaluated for the 5105 cows that were examined during the first visit to the herds. Daily milk yields for individual cows were recorded 11 times a year. All milk yields recorded during the lactation where the cow was observed were included in the analysis. Each parity (1, 2, and 3 or older) was analysed separately. We used the PROC MIXED procedure of SAS (Statistical Analysis System, version 8) with the outcome being milk production (kg ECM) and the explanatory variables: Loser cow state, days in milk (DIM) and breeding value for milk production. Breeding value for milk production (BV) was included to take differences in the genetic potential for milk production into account. BV was defined as:

$BV= 0.5*(\text{breeding value for milk production}_{dam} + \text{breeding value for milk production}_{sire})$

This way the cows own milk production only influenced the breeding value for milk production minimally. Stage of lactation was modelled as DIM, and an exponential function to the power –0.05 DIM (Wilmink, 1987). We included interactions between loser cow state and stage of lactation to test for differences in the shape of the lactation curve. The average daily milk yield during the lactation was estimated in a model without these interactions. Repeated measures within cows were modelled using an unstructured correlation structure. Herd was included as a random effect.

Mortality. The relation between the loser cow state and mortality was evaluated using a Cox proportional hazards model (Cox, 1972). The outcome was survival time in days from calving to death or euthanasia. Cows that were slaughtered or sold for dairy purposes and cows that were still in the herd 1st October 2004 were censored (right censoring). Loser cow state and parity (1, 2, and 3 or older) were included as predictors. We used the PROC PHREG procedure of SAS with the Breslow approximation of the marginal calculation (Breslow, 1974). The significance level for the confidence limits for the hazard ratios was set at 0.05. Interactions between the predictors and possible confounding were evaluated. The assumption of proportional hazards was tested by examining the log-cumulative hazard plot ($\ln H(t)$ vs. $\ln t$). We used deviance residuals to check for outliers (Dohoo et al., 2003).

Culling time. The relation between the loser cow state and culling time was evaluated as described for mortality above. The only difference was that the outcome was survival time in days from calving to death, euthanasia or slaughter. All cows leaving the herd (except cows sold for dairy purposes) were thus considered culled. Cows that were sold for dairy purposes and cows that were still in the herd 1st October 2004 were censored (right censoring).

Culling mode. Culling mode was recorded by the farmer each time a cow left the herd. The farmer used the categories dead, euthanised, slaughtered or sold for dairy purposes. A total of 1314 cows examined during the first visit to the herds were culled before 1st October 2004 and hence included in the analysis. The effect of the loser cow state on the culling mode was analysed using hierarchical log-linear models. P-values for tests of independence in ‘r’ by ‘c’ tables (Patefield, 1981) and p-values for tests of conditional independence given herd (Kreiner, 1987) were computed by Monte Carlo approximation. The software used was the graphical modelling program ‘CoCo’ (Badsberg, 2001).

Workload. Workload was recorded by the farmer each time a cow left the herd. The farmer assessed the workload associated with the cow as either 'no extra work compared to an average cow in the herd', 'a little extra work' or 'much extra work'. The extra workload could be both a few minutes of extra work on a daily basis during a relatively long period of time or a lot of extra work (hours) on one occasion. A total of 1314 cows examined during the first visit to the herds were culled before 1st October 2004 and hence included in the analysis. The effect of the loser cow state on the workload was analysed using hierarchical log-linear models. P-values for tests of independence in 'r' by 'c' tables (Patefield, 1981) and p-values for tests of conditional independence given herd (Kreiner, 1987) were computed by Monte Carlo approximation. The software used was the graphical modelling program 'CoCo' (Badsberg, 2001).

Diseases. Disease treatments were recorded by the farmer or by the local veterinarian (depending on who performed the treatment). Treatment of a disease on several successive days were recorded as only one treatment as treatments within a period of 8 days after the first treatment were not recorded as new treatments. We analysed the effect of the loser cow state on the number of treatments in the lactation where the cow was observed using a Poisson regression model. All cows observed during the first visit to the herds (N=5105) were included in the analysis. We used the PROC GENMOD procedure of SAS with the number of disease treatments (0, 1, 2, 3, or 4 or more) as the outcome and loser cow state and parity (1, 2, or 3 or older) as the explanatory variables. First we used treatments for all diseases as the outcome and secondly we used treatments for all diseases excluding mastitis as the outcome. This was done because mastitis accounted for a large proportion of all treatments, but mastitis was considered less important in relation to the loser cow state. To take different practices regarding treatment of diseased cows into account, the herd was included in the model as a random effect. To adjust for different amounts of time at risk for individual cows we used the time in days from calving to death, euthanasia, slaughter or sale for dairy purposes as an offset (Dohoo et al., 2003). Overdispersion was measured by the deviance divided by the degrees of freedom (Woodward, 1999).

Alternative Definitions of Loser Cows

The 'original' clinical protocol included 7 clinical signs. The prevalence of deviations from the normal condition for these clinical signs was expected to vary from sign to sign. Clinical signs where deviations from the normal condition have a low prevalence add little information at the cost of relatively much extra work (Streiner and Norman, 2003). We therefore wanted to evaluate a simplified loser cow score, where clinical signs with a low prevalence were omitted. Clinical signs with a prevalence of deviations from the normal condition below 5 % were omitted in a 'simple loser cow score'. Such principles of omission has been described by Streiner and Norman (2003).

We wanted to evaluate the relation between the new 'diagnosis' loser cow and lameness in order to evaluate whether the loser cow concept would rather be a complex combination of several clinical entities than consisting merely of a single well-known clinical entity. Lameness was one of the clinical signs included in the clinical protocol. The maximum number of points that a cow could attain for lameness was 8 (given to a severely lame cow). A cow may therefore become classified as a loser cow solely on the basis of lameness (explanation of the classification of cows as loser cows is given in the results section). We therefore wanted to evaluate whether a loser cow is in fact just another way of describing a lame cow. To do so, we calculated the consequences of being lame in the same way as described for loser cows in the previous section. Furthermore, we calculated a loser cow score where lameness was not included. We termed this score 'loser cow score-minus-lameness'. This score was identical to the loser cow score except that lameness was not included.

Effect of Season
We evaluated the effect of season on the occurence of loser cows. We compared the mean loser cow score in the herds during the seasons spring (March – May), summer (June – August), fall (September – November) and winter (December - February). In order to take the large variation among herds into account we also recorded the season with the highest mean loser cow score for each herd separately.

Results

Descriptive statistics of the 39 herds in the study compared to all Danish dairy herds are shown in Table 3. The vast majority of the cows in the herds were examined. Overall 97.4 % of the cows that were in the herds the day of the visit were examined. In 35.7 % of the visits, all the cows in the herd were examined and in 57.4 % of the visits, more than 98 % of the cows in the herd were examined.

Table 3. Descriptive statistics of 39 Danish dairy herds participating in a study of loser cows compared to all Danish dairy herds participating in milk recording. Data on all Danish dairy herds are from Anon. (2005). * Average milk yield is for herds with Danish Holstein as the predominant breed only.

	Study herds	All Danish dairy herds
Herd size, cows	136.8	85.8
Average milk yield, kg ECM	9,587	8,900*
Average somatic cell count, cells/ml	258,100	225,600
Average bacterial count in milk, bacteria/ml	9,830	6,990

A total of 15,151 observations were made during the three visits to the 39 herds (5105 cows examined during the first round of herd visits, 5145 during the second round and 4901 during the third round). The distribution of loser cow scores for these cows is shown in Figure 1.

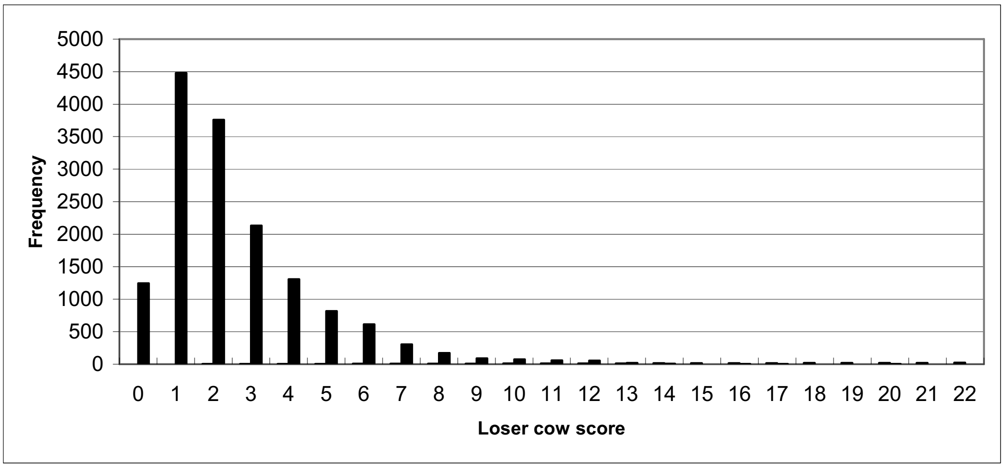

Figure 1. The distribution of loser cow scores for 15,151 Danish dairy cows in a study of loser cows. See text for further explanations.

The mean loser cow score was 2.53, the minimum loser cow score observed was 0 and the maximum loser cow score observed was 22. Thus, no cow was assigned the theoretical maximum loser cow score of 32. The individual cow might be examined more than once. Of the 5105 cows examined in the first round, 4332 were examined again in the second round and 3589 were also examined in the third round. Figure 2 shows the mean loser cow score in each of the 39 herds.

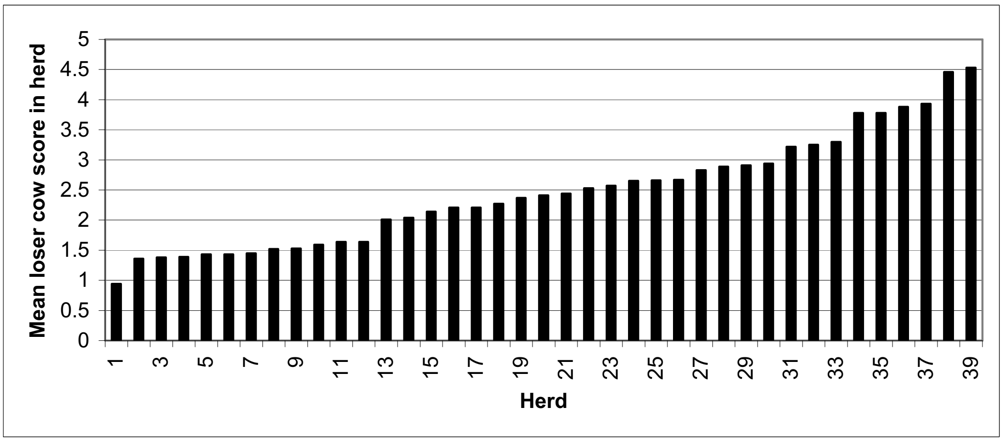

Figure 2. The mean loser cow score in 39 Danish dairy herds participating in a study of loser cows. Herds are ordered on the basis of mean loser cow score. See text for further explanations.

Figure 3 show the distribution of loser cow scores in two herds: One herd with a low mean loser cow score (herd 1 in Figure 2) and one herd with a high mean loser cow score (herd 38 in Figure 2).

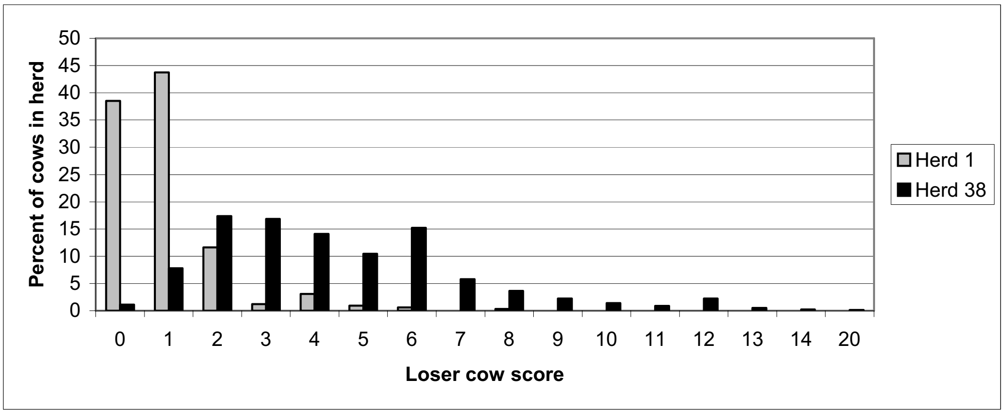

Figure 3. The distribution of loser cow scores in two herds in a study of loser cows in Danish dairy herds. See text for further explanations.

Figure 4 shows the indexed consequences of different cut-offs between loser cows and non loser cows. No large, sudden change in the consequences between any two adjacent cut-offs was found. We chose 8 as the threshold: Cows with a loser cow score of 8 or more were classified as loser cows. This threshold was applied to all the results presented hereafter. The overall prevalence of loser cows using this definition was 3.24 %. The prevalence of loser cows in the 39 herds ranged from 0 % to 11.49 % (Q1: 0.68; median: 1.89; Q3: 3.04).

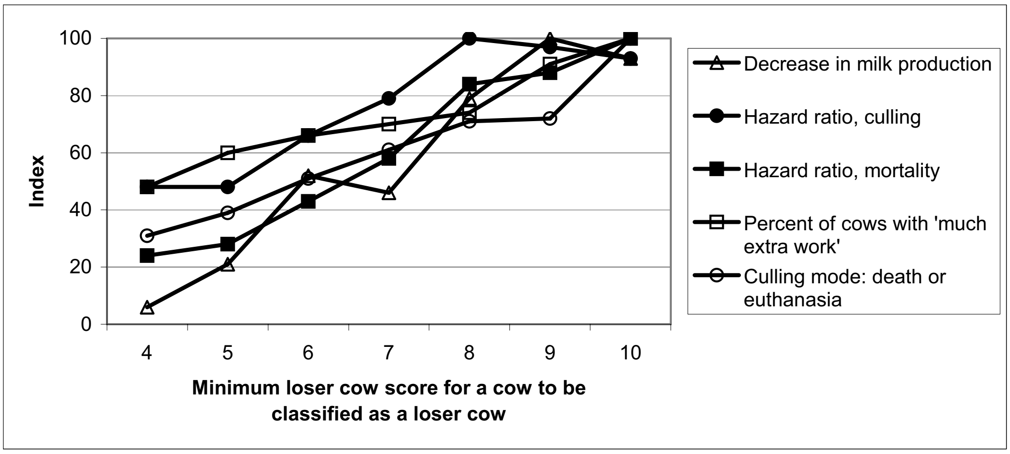

Figure 4. Indexed consequences of the loser cow state on decrease in milk production, hazard ratio for culling, hazard ratio for death or euthanasia, percentage of cows with 'much extra work' and percent cows with culling mode 'death or euthanasia' from a Danish study of loser cows. See text for further explanations.

Consequences of the Loser Cow State

Milk production. The effect of the loser cow state on milk production was analysed for the effect on the shape of the lactation curve and on the average daily milk yield during the lactation. Significant effect of loser cow state on the shape of the lactation curve was found only for parity 1. The exponential term in the Wilmink function describing the production increase toward peak yield differed, so that loser cows peaked earlier than non loser cows in parity 1. The average daily milk yield during the lactation was reduced significantly for all parities ($p=0.06$ for parity 1, $p<0.0001$ for parities 2 and 3 or older). On average loser cows yielded 0.64 (standard error: 0.33), 2.24 (0.46) and 1.52 (0.31) kg ECM per day less than non loser cows during first, second and later lactations, respectively.

Mortality. The hazard ratio for death or euthanasia was 5.69 (95 % confidence interval: 3.93 – 8.23, $p<0.0001$) for loser cows compared to non loser cows. Parity also had a statistically significant effect on survival (hazard ratio for second parity cows compared to first parity cows was 1.51 (1.11-2.04, $p=0.0084$), hazard ratio for third parity or older cows compared to first parity cows was 2.44 (1.87-3.18, $p<0.0001$)). We found no interaction between loser cow state and parity and no biologically relevant confounding. Examination of the log-cumulative hazard plot indicated that the assumption of proportional hazards was not violated. Examination of the deviance residuals revealed no problems with outliers.

Culling time. The hazard ratio for death, euthanasia or slaughter was 2.55 (95 % confidence interval: 2.00 – 3.26, $p<0.0001$) for loser cows compared to non loser cows. Parity also had a statistically significant effect on culling time (hazard ratio for second parity cows compared to first parity cows was 1.82 (1.58-2.09, $p<0.0001$), hazard ratio for third parity or older cows compared to first parity cows was 2.56 (2.25-2.91, $p<0.0001$)). We found no interaction between loser cow state and parity and no biologically relevant confounding. Examination of the log-cumulative hazard plot indicated that the assumption of proportional hazards was not violated. Examination of the deviance residuals revealed no problems with outliers.

Culling mode. The distribution of culling modes for loser cows and non loser cows, respectively, is shown in Table 4. Differences between loser cows and non loser cows were highly significant (p=0.003) and conditional on herd this dependence remained significant (p=0.001). Thus, the effect of loser cow state on culling mode was not an effect of herd.

Table 4. Distribution of culling modes for 1314 culled cows in a study of loser cows in Danish dairy herds. See text for further explanations.

	Percent dead	Percent euthanised	Percent slaughtered	Percent sold for dairy purposes
Non loser cows	5.78	4.44	86.37	3.41
Loser cows	15.38	13.46	69.23	1.92

Workload. The distribution of the farmers' assessments of the workload associated with cows that were culled is shown in Table 5. Differences between loser cows and non loser cows were highly significant (p=0.004) and conditional on herd this dependence remained significant (p<0.0001). Thus, the effect of loser cow state on workload was not an effect of herd.

Table 5. Distribution of the farmers assessment of the amount of work associated with 1314 culled cows in a study of loser cows in Danish dairy herds. See text for further explanations.

	Percent with 'no extra work'	Percent with 'a little extra work'	Percent with 'much extra work'
Non loser cows	74.11	19.64	6.25
Loser cows	53.85	30.77	15.38

Diseases. Incidence rate ratio (IR) for disease treatments (all diseases) was 0.69 (95 % confidence interval: 0.55 – 0.86, p=0.0022) for non loser cows compared to loser cows and the IR was 0.56 (95 % confidence interval: 0.44 – 0.70, p=0.0005) for all diseases excluding mastitis. Thus, the number of disease treatments among non loser cows was significantly lower than among loser cows. We considered the overdispersion acceptable (1.18 and 1.12, respectively).

Alternative Definitions of Loser Cows

The observed prevalence of deviations from the normal condition was below 5 % for the clinical signs vaginal discharge, general condition and body condition score (1.43 %, 0.13 %, and 0.84 %, respectively). These clinical signs were therefore omitted in the simple loser cow score. Table 6 presents the simple loser cow score. Only 355 of the 15,151 observed cows had deviations from the normal condition in any of the clinical signs vaginal discharge, general condition or body condition score. Therefore, the loser cow score and the simple loser cow score were the same for 97.7 % of the cows observed. A total of 47 cows had a loser cow score of 8 or more and a simple loser cow score below 8. Approximately 10 % of the cows classified as loser cows using the loser cow score were classified as non loser cows using the simple loser cow score.

Table 6. Conversion of the clinical scores into points for a 'simple loser cow score' in a Danish study of loser cows. Points are shown as the raised numbers for each clinical score.

Lameness	1^0 2^1 3^2 4^4 5^8
Hock lesions	1^0 2^0 3^1 4^2
Other cutaneous lesions	1^0 2^0 3^1 4^2
Skin condition	1^0 2^1 3^2

Table 7 summarises the differences between being a loser cow and being a lame cow. The table compares the consequences of having a loser cow score of 8 or more (original definition of a loser cow), being a lame cow (lameness score >= 3) and having a loser cow score-minus-lameness of 4 or more. The reason for the choice of 4 as the threshold for the loser cow score-minus-lameness is that the proportion of cows being classified as loser cows using this definition approximately equals the proportion of cows having a loser cow score of 8 or more (3.63 % and 3.24 %, respectively).

Table 7. Comparison of the consequences of different definitions of loser cows and lame cows in a Danish study of loser cows. See text for further explanations.

	Loser cow score >= 8	Lame cows	Loser cow score-minus-lameness>=4
Decrease in milk production, kg ECM (305 day lactation)	356	-103	58
Hazard ratio, mortality	5.69	1.24	6.10
Hazard ratio, culling	2.55	1.15	2.47
Percent of cows with much extra work	15.4	7.5	12.8
Culling mode: death or euthanasia, percent	28.9	11.6	36.0

Effect of Season

The number of cows examined each season and the mean loser cow score for each season are summarised in Table 8. In 18 of the 37 herds that were visited three times the highest mean loser cow score were registered in spring, 9 herds had the highest mean loser cow score in winter, 5 herds had the highest mean loser cow score in fall and 5 herds had the highest mean loser cow score in summer.

Table 8. Mean loser cow score at the herd level and number of cows examined each season in a Danish study of loser cows. See text for further explanations.

Season	All herds (N=37)	Herds with cows on pasture (N=18)	Herds without cows on pasture (N=19)
Summer (N=3682)	2.23	1.35	3.13
Fall (N=3431)	2.33	1.45	2.99
Winter (N=4361)	2.58	1.96	2.96
Spring (N=3677)	2.97	2.26	3.80

Discussion

The selection of large (> 100 cows) herds with loose-housing systems were based on the assumption that this type of herd will become ‘the herd of the future’ in Danish dairy production. The herds in the study were all members of a milk control association, their cows were conformation scored, disease recordings were acceptable and the farmers were willing to participate in the project even though this gave them extra paperwork (registration of workload, culling mode and reason when a cow was culled). The farmers were not paid for their participation in the project. By selecting herds with these characteristics we expected to get much information of a high quality. The disadvantage of this selection procedure was that the selected herds might not be considered as a representative sample of the population of Danish dairy herds. We found that some degree of selection was needed to ensure adequate information of an acceptable quality. We believe that the herds selected for this study do not differ from other Danish dairy herds in any systematic way. We therefore believe that the conclusions from this study are valid for all large Danish dairy herds with loose-housing systems.

To keep transportation times at a reasonable level we had made geographical restrictions regarding the herds that were invited to participate in the study. The area from where the herds were selected houses approximately 2/3 of the Danish dairy cattle population (Anon., 2004).We have no reason to believe that dairy herds in this part of Denmark differ from other Danish dairy herds in any systematic way.

Figure 4 shows that the negative consequences of being a loser cow compared to a non loser cow gradually increases with increasing cut-off between the two groups. We found no large, sudden change in the consequences between any two adjacent cut-offs. From Figure 4 it can be seen that the increase in the negative consequences for cut-offs over 8 is limited. Still, the choice of the loser cow score 8 as the minimum score for a cow to be classified as a loser cow is somewhat arbitrary.

Culling of a certain percentage of the cows in a dairy herd every year is inevitable (and often desired due to the genetic superiority of younger animals). However, how these cows are culled matters. Both financially and in relation to animal welfare the preferred culling mode is sale for dairy purposes, followed by slaughter, euthanasia and finally death. Table 4 shows that the percentage of cows that died or were euthanised was approximately three times as high among cows classified as loser cows compared to non loser cows. The risk of being culled in an ‘unfavourable’ way was, in other words, much higher for loser cows.

Very few cows had deviations from the normal condition regarding the clinical signs vaginal discharge, general condition and body condition score. The number of cows where the loser cow score and the simple loser cow score were not identical therefore was very limited. We find that the little extra information contained in the loser cow score compared to the simple loser cow score do not warrant the extra work associated with observation of 7 clinical signs compared to 4 clinical signs. For future evaluations of the loser cow state we therefore recommend that the simple loser cow score is used. Scoring of 40 – 50 cows in one hour by an observer with only a limited amount of training is realistic.

From Table 7 it is evident that the negative consequences of being a loser cow are considerably larger than the negative consequences of being a lame cow. In Table 7 only cows with a lameness score of 3 or more were classified as lame. If all cows with a lameness score of 2 or more had been classified as lame the magnitude of the negative consequences of lameness would have been even smaller. The negative consequences of being a cow with a loser cow score-minus-lameness of 4 or more were substantially larger than the negative consequences of being a lame cow. We therefore conclude that the loser cow score (and, hence, the concept of loser cows) is relevant, as loser cows are different from, and more than just, lame cows. Nevertheless, lameness may in many instances be an important characteristic of a loser cow.

There seems to be a tendency for higher loser cow scores during the winter and, even more pronounced, in spring. In herds, where the cows are on pasture during the summer, the reason behind this might be that grazing (and the consequent exercise) has a positive influence on health in general. Gustafson (1993) concluded that health in general was significantly influenced by exercise, reducing the frequency of veterinary treatment. Alban and Agger (1996) concluded that grazing was associated with better health. Regula et al. (2004) concluded that loose-housing and regular outdoor exercise had several positive effects on the health and well-being of dairy cows. Thomsen et al. (2005) concluded that the mortality risk in dairy herds where the cows were on pasture during the summer was reduced. The highest mean loser cow score was found in spring when the cows had not been on pasture for the longest time.

The pathogenesis of the loser cow state is unknown. Most likely, a loser cow can evolve in several ways. One possible scenario might be a cow that for some reason becomes (chronically) lame. The lame cow will be reluctant to walk and stand. She lies down a larger proportion of the day compared to a normal cow. This causes a reduced feed intake, which in turn causes a decreased milk production. She is having difficulty lying down and getting up. Therefore she often hits the cubicle partitions getting up or lying down. This results in contusions in different parts of the body. These contusions might become infected, etc. We believe that a loser cow often starts with a harmful event (e.g. dystocia or lameness) and if the cow is not able to recover from this event, she will get into a 'vicious circle' as described above.

In a modern dairy operation the number of man hours per cow is limited (Barrett, 2004). A cow where extra work is needed therefore often disturbs the daily routines in the herd. The percentage of cows where the farmers recorded that the cow had caused a little or much extra work generally was twice as high for loser cows as for non loser cows (Table 5).

We found a statistically significant effect of the loser cow state on the number of disease treatments in the lactation where the cow was observed. We used all disease treatments in the whole lactation where the cow was observed as a measure of morbidity, but we had no information about the loser cow state of the cow other than at the specific point in time where she was observed and scored. We therefore did not know whether a cow observed 8 months after calving had been a loser cow since the beginning of the lactation or just for the last three weeks. The number of disease treatments during the whole lactation might therefore not be a good measure of morbidity. One might consider using the number of treatments *after* the cow had been observed and scored as a measure of morbidity. We used the number of disease treatments as a measure of the morbidity. The number of recorded treatments is not necessarily a good indicator of the morbidity (Houe et al. 2004; Klaas et al., 2004). There is a number of steps from a cow being sick to a treatment record. If the farmer does not observe that the cow is sick, no treatment is initialised and hence no treatment is recorded. If the farmer observes that the cow is sick, he/she might for different reasons decide not to treat the cow (Vaarst et al., 2002). Again no treatment is recorded. And finally, if the farmer observes a sick cow and decides to treat her, the treatment might not be recorded correctly. It is our perception that diseases among loser cows often are chronic (e.g. lameness or contusions). Therefore, farmers often may resign and omit treating loser cows as they may find treatment futile.

As the loser cow state until now has not been investigated scientifically we have no data indicating whether the problem has increased over time. A relatively large proportion of the loser cows die or are euthanised. Mortality among dairy cows may therefore be regarded as 'the top of the iceberg' regarding the loser cows. Mortality among Danish dairy cows has doubled from 2 % in 1990 to 4 % in 2001 (Thomsen et al., 2004). This might indicate that the problems with loser cows have also increased over time.

From Figures 2 and 3 it is obvious that there is a large difference in the mean loser cow score among herds. The reasons for this difference will not be addressed in this paper, but further research in this area is recommended.

Conclusions

A loser cow is a new clinical entity. We defined a loser cow on the basis of a clinical examination. Scores for the clinical signs lameness, body condition, hock lesions, other cutaneous lesions, vaginal discharge, skin condition and general condition were converted into a loser cow score. Cows with a loser cow score of 8 or more were classified as loser cows. The overall prevalence of loser cows in a random sample of large, Danish dairy herds were 3.24 %.

The loser cow state has significant negative consequences on milk production, mortality, morbidity, culling and workload for the farmer. A simplified version of the loser cow score is recommended for future research and use in practice.

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9. Loser Cows in Danish Dairy Herds: Risk Factors

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Submitted

Interpretive summary

Loser Cows in Danish Dairy Herds: Risk Factors, *by Thomsen et al.*

Risk factors for the loser cow state were evaluated among Danish dairy cows. Herds with a high average somatic cell count, a high calf mortality, many stillborn calves, hard cubicles and no grazing seem to be associated with a high proportion of loser cows. Additionally, older cows seem to be at greater risk than younger cows. The loser cow state has severe negative effects for both the cow and the farmer and evaluation of potential risk factors may be used as a tool to reduce the problems with loser cows.

Abstract

The objective of our study was to evaluate risk factors for the loser cow state in Danish dairy cattle herds. We used correspondence analysis to give a first indication of the associations between the proportion of loser cows in the herd and potential risk factors. Risk factors were evaluated both at the herd level (39 herds) and at the cow level (6,451 cows) using logistic regression. Herds with a high average somatic cell count, a high calf mortality, many stillborn calves, hard cubicles and no grazing seem to be associated with a high proportion of loser cows. At the cow level odds ratio for the loser cow state increases significantly with increasing parity. Odds ratio for the loser cow state were 0.16, 0.41 and 1 for parity 1, 2 and 3 or older, respectively.

Key words: loser cow, risk factor, correspondence analysis, logistic regression.

Introduction

During the last few years, many Danish dairy farmers have noticed a group of cows commonly termed 'loser cows'. A feasible definition of a loser cow based on a clinical examination of the individual cow has been suggested (Thomsen et al., 2005b). The clinical examination included evaluation of body condition score, lameness, hock lesions, other cutaneous lesions, vaginal discharge, skin condition and general condition. Recordings of clinical signs were converted into a loser cow score. A loser cow was defined as a cow with a loser cow score of 8 or more. The effect of the loser cow state on milk production, morbidity, mortality, culling and extra workload for the farmer was evaluated and it was concluded that the loser cow state had severe negative consequences for both the farmer and the cow (Thomsen et al., 2005b). Loser cows had a significantly increased hazard ratio for death and culling and a high percentage of the loser cows died or were euthanised. The loser cow state was associated with a decrease in milk production, morbidity among loser cows generally were twice as high as among non loser cows, and the farmers in general estimated that a loser cow caused extra work compared to an 'average' cow in the herd. Therefore, loser cows are undesirable both financially and in relation to animal welfare. Thomsen et al. (2005b) estimated a prevalence of loser cows in Danish dairy herds of approximately 3 percent. On way of controlling the problems with loser cows can be to identify risk factors for the loser cow state. Identification of these risk factors can give veterinarians and agricultural advisors a knowledge that could form the basis of advise, which could reduce the number of loser cows in the dairy herds.

The objectives of our study were to evaluate risk factors for the loser cow state, both at the cow level and at the herd level.

Materials and methods

Selection of Herds

Forty herds were randomly selected among Danish dairy herds that met the following criteria: Loose-housing system, more than 100 cows during the period 1st October 2001 to 30th September 2002, primarily Danish Holstein (more than 95 % of the cow days in the herd constituted by Danish Holstein), herd participating in milk recording (member of a Milk Control Association) and cows being conformation scored by breeding inspectors from a cattle breeding organisation. Additionally, only herds in a distance of less than approximately 150 km from the Danish Institute of Agricultural Sciences, Foulum, and herds with an acceptable level of disease recordings prior to the start of the study were considered when the herds were sampled. Among the herds that met these inclusion criteria 40 herds with a co-operative farmer were selected randomly. One herd was excluded from the study due to problems with the farmer's record keeping and an inability for us to examine all the cows in the herd. Thus, a total of 39 Danish dairy herds participated in the study. A thorough description of the selection of herds can be found in Thomsen et al. (2005b).

Selection of Herd Level Explanatory Variables for Analysis

In total 189 potential herd level explanatory variables were collected both from the Danish Cattle Database and during herd visits. At the start of the study, the farmers were interviewed regarding management, daily routines, plans for the future etc. Research technicians from the Danish Institute of Agricultural Sciences recorded information regarding the physical characteristics of stables, cubicles, use of bedding, milking system etc. All information about these variables were collected during the period 1st October 2003 to 30th September 2004. Before the analysis this large number of potential explanatory variables had to be reduced. Dohoo et al. (2003) states that using a few explanatory variables with a high data quality should be preferred. We wanted the explanatory variables to give an 'overall picture' of the management and the physical characteristics of the herds. We therefore chose 1-4 variables of a high data quality regarding each of the main areas: management, farmer's attitude, physical facilities, hygiene, production results, farmer's experience and herd size. Whether an explanatory variable was to be considered of 'high data quality' depended on a subjective assessment based on our knowledge of the origin of the information. A total of 13 explanatory variables were chosen (Table 1).

All herds were visited three times with an interval of approximately 120 days during the period September 2003 to October 2004. A total of 15,151 cows were examined and assigned a loser cow score (5105 cows examined during the first round of herd visits, 5145 during the second round and 4901 during the third round). All cows with a loser cow score of 8 or more were defined as loser cows (Thomsen et al., 2005b). The variables in the initial list of explanatory variables (Table 1) were used as input in a correspondence analysis to analyse the relationship among qualitative variables. The main result of a correspondence analysis is a visual summary (usually two-dimensional) of the complex relationship among a set of qualitative variables (both explanatory variables and the outcome). The two axes are factorial axes reflecting the most inertia (variability) in the original explanatory variables. The resulting scatterplot identifies clusters of explanatory variables that are closely associated, with clusters farther from the intersection of the axes having stronger associations. A qualitative outcome variable can also be projected on the same axes to

Table 1. Initial list of explanatory variables in a study of risk factors for the loser cow state in 39 Danish dairy herds. The variables are grouped in 7 main areas giving an overall description of the herds.

Main area	Explanatory variables
Management	Proportion of stillborn calves Calf mortality during the first 30 days of life
Farmer's attitude	Farmer's expectations regarding the future herd size Organic or conventional herd
Physical facilities of the farm	Number of cows per cubicle Number of cows per feeding place Stall surface Use of grazing
Hygiene	Average bacterial count in milk
Production results	Average milk yield Average somatic cell count
Farmer's experience	Farmer's years of experience working with cows
Herd size	Herd size (number of cows)

determine which clusters of explanatory variables are associated with the outcome of interest (Dohoo et al., 1996, Dohoo et al., 2003). We made a multiple correspondence analysis using the PROC CORRESP procedure of SAS (Statistical Analysis System, version 8) with the variables presented in Table 1 as the active (explanatory) variables and the proportion of loser cows in the herds as the illustrative (outcome) variable. Correspondence analysis more clearly demonstrates associations when the illustrative variable is coded in three or more levels (Dohoo et al., 1996). All quantitative variables were made qualitative based on quartiles. Values from the minimum value to the first quartile (minimum to Q1), values from the first to the third quartile (Q1 to Q3) and values from the third quartile to the maximum value (Q3 to maximum), respectively, were grouped together. The categorisation of the variables for the correspondence analysis is presented in Table 2. In this way, we ended up with three levels of each of the quantitative active and illustrative variables. We included all observations made during the first visit to the herds (5,097 cows from the 39 herds) in the analysis. The result of the correspondence analysis was used as a first indication of associations between the explanatory variables and the proportion of loser cows in the herds. We also used the correspondence analysis as a possible way to reduce multicollinearity (Dohoo et al., 1996). If two or more explanatory variables were closely associated in the correspondence analysis we included only one of them in the subsequent analyses.

After the correspondence analysis the unconditional associations between the herd level explanatory variables (Table 1) and the proportion of loser cows in the herd was evaluated using a logistic regression model with the number of loser cows divided by the total number of cows examined in the herd as the outcome and one potential risk factor at a time as the explanatory variable. Only cows examined during the first of the three herd visits (N=5,097) were included in the analysis. We used the PROC GENMOD procedure of SAS for this evaluation. All explanatory variables with a p-value below 0.1 in this analysis were included in the final multiple logistic regression analysis for herd level risk factors.

Herd Level Risk Factors

We used logistic regression (the PROC GENMOD procedure of SAS) to evaluate potential herd level risk factors for the loser cow state. All cows examined during the first of the three visits to the herds in the study (5,097 cows from 39 herds) were included in the analysis. Of these cows 107 with a loser cow score of 8 or more were defined as loser cows (Thomsen et al., 2005b). The outcome was the number of loser cows divided by the total number of cows examined in the herd. The explanatory variables were the proportion of stillborn calves, calf mortality during the first 30 days of life, average bacterial count in milk, average somatic cell count, herd size, the farmer's expectations regarding the future size of the herd, organic or conventional herd, number of cows per cubicle, stall surface and use of grazing. The former 5 were quantitative and the latter 5 were categorical. Linearity between the quantitative explanatory variables and the outcome (logit (p)) was checked by categorizing the quantitative explanatory variables into three levels. For each explanatory variable the levels were based on quartiles as described above. Whenever this relation was approximately linear, the explanatory variable was included in the analysis as a quantitative explanatory variable. The model was reduced using backward elimination with explanatory variables with a p-value >0.05 being removed sequentially from the model (Dohoo et al., 2003).

All possible two-factor interactions between the explanatory variables in the final model were included (one by one) in the final model. The use of backward elimination assesses the statistical significance of terms after adjustment for the potential confounding effect of other variables in the model (Dohoo et al., 2003). Additionally, we checked possible confounding by calculating odds ratios (OR) for the risk factors with and without the possible confounder included in the model (Woodward, 1999). All biologically plausible confounding were checked this way. Whenever the change in OR with and without the possible confounder included in the model was less than 20 % the confounding was considered of no biological interest (Hosmer and Lemeshow, 2000, Dohoo et al., 2003). The overall fit of the model was evaluated using the overdispersion parameter, the Pearson χ^2 test, the deviance χ^2 test and the Hosmer-Lemeshow goodness-of-fit test (Woodward, 1999, Hosmer and Lemeshow, 2000, Dohoo et al., 2003).

Cow Level Risk Factors

We used a random effects logistic regression model (the PROC GENMOD procedure of SAS with the repeated statement) to evaluate potential cow level risk factors for the loser cow state. All cows examined during one or more of the three herd visits were included in the analysis. Cows examined more than once were only included in the analysis once by random sampling. This was done to take the effect of season on the prevalence of loser cows into account (Thomsen et al., 2005b). A total of 6,451 cows were included in the analysis. Of these cows, 172 with a loser cow score of 8 or more were defined as loser cows (Thomsen et al., 2005b). The outcome was loser cow (yes/no) and the explanatory variables are presented in Table 3. Information about parity, month of calving, status regarding purchase, age at first calving, breeding value for milk production and height was obtained from the Danish Cattle Database. Information about the course of the last calving was recorded by the farmer. Height was recorded as the hip height as described by Enevoldsen and Kristensen (1997) by breeding inspectors from the cattle breeding organisation 'Dansire' during the first part of the first lactation. As cows still grow during the first lactation, the measured height was adjusted according to time after calving (0.1 cm was added to the measured height for every month prior to 4 months after calving) (Anon., 2003). Breeding value for milk production (BV) was defined as:

$BV= 0.5*(\text{breeding value for milk production}_{dam} + \text{breeding value for milk production}_{sire})$.

This way the cows own milk production only influenced the breeding value for milk production minimally. Calculation of breeding value for milk production has been described by Nygaard (2002). Due to the relatively small number of explanatory variables no reduction in the number of explanatory variables was done prior to the analysis. To take clustering of cows in herds into

Table 2. Descriptive characteristics of the 39 herds in the study and categorisation of active (explanatory) and illustrative (outcome) variables for correspondence analysis in a Danish study of risk factors for the loser cow state.

Variable	Possible categories of variable	Definition of categories
Stall surface	Soft cubicles Hard cubicles	Straw, sand, sawdust, wood shavings and free stall barns with deep litter Concrete, rubber mats, rubber mattresses
Farmer's expectations regarding future herd size	Unchanged herd size Increasing herd size	
Somatic cell count (herd average)	Low Intermediate High	cells/ml<200,000 200,000<= cells/ml <300,000 cells/ml>= 300,000
Herd size	Low Intermediate High	cows<115 115<= cows <156 cows >= 156
Bacterial count in milk (herd average)	Low Intermediate High	bacteria/ml < 5100 5100<= bacteria/ml <9800 bacteria/ml >=9800
Grazing	Grazing No grazing	
Organic herd	Organic Conventional	
Milk yield (herd average)	Low Intermediate High	kg ECM<9200 9200<=kg ECM<10.100 kg ECM>=10.100
Farmer: Years of experience with cows	Young Middle-aged Old	years<15 15<=years<30 years>=30
Calf mortality during the first 30 days of life	Low Intermediate High	mortality risk<0.02 0.02<=mortality risk<0.05 mortality risk>=0.05
Proportion of stillborn calves	Low Intermediate High	Proportion<0.06 0.06<=proportion<0.11 proportion>=0.11
Number of cows per cubicle	Low Intermediate High	cows<0.95 0.95<=cows<1.08 cows>=1.08
Number of cows per feeding place	Low Intermediate High	cows<1.08 1.08<=cows<1.43 cows>=1.43
Proportion of loser cows in herd	Low Intermediate High	Proportion=0 0<proportion<0.031 proportion>=0.031

account the herd was included in the model as a random effect. The repeated statement in PROC GENMOD uses generalised estimating equations to obtain population-averaged estimates for clustered data. We specified a compound symmetry correlation structure (=exchangeable correlation structure) (Hosmer and Lemeshow, 2000, Dohoo et al., 2003). Linearity between the quantitative explanatory variables and the outcome (logit (p)) was checked as described for the herd level analysis above. Reduction of the model, control for interactions and confounding was done as described for the herd level analysis above. The overall fit of the model was evaluated using a Hosmer-Lemeshow goodness-of-fit test assuming that the observations were not correlated (Hosmer and Lemeshow, 2000).

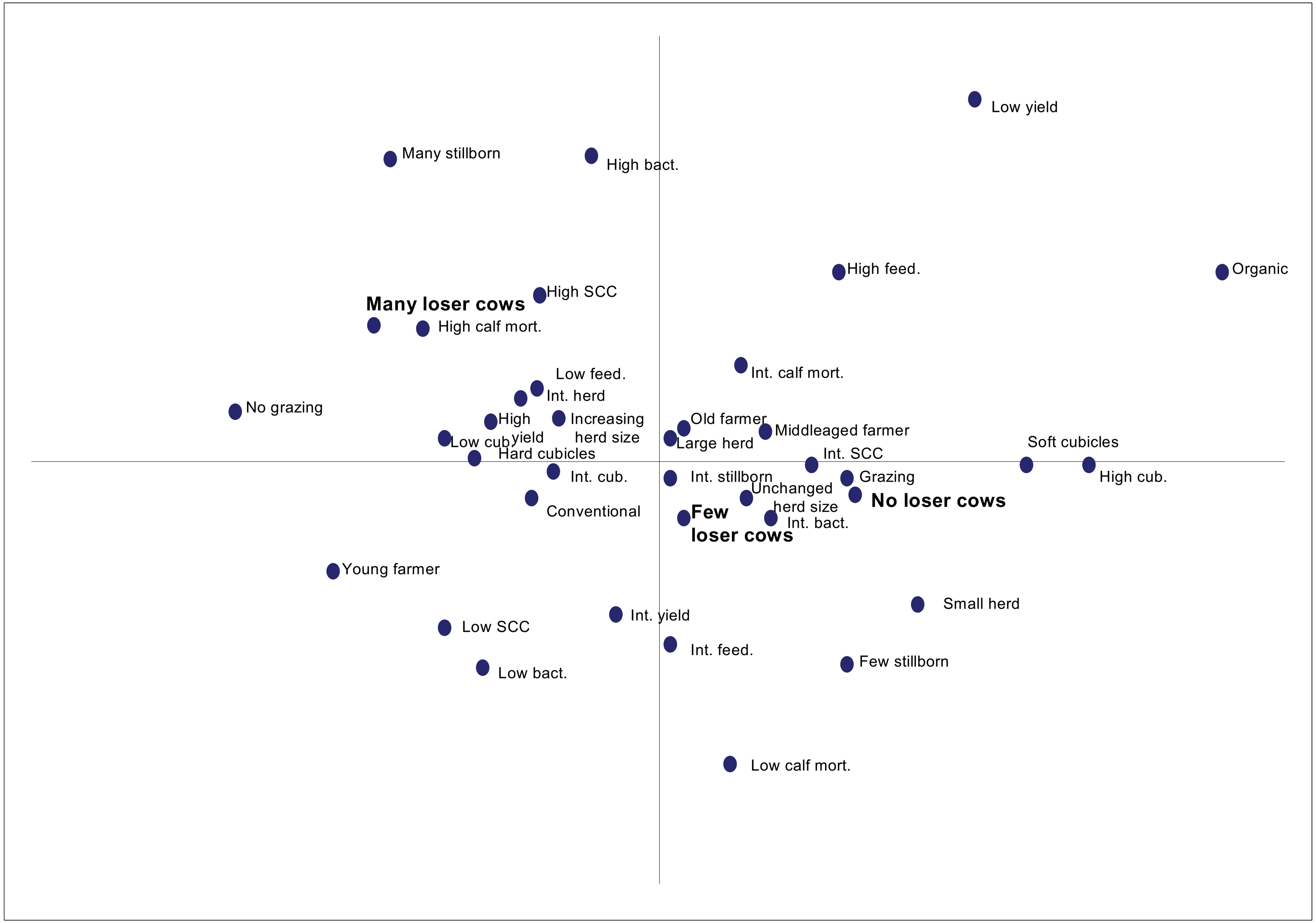
Table 3. Explanatory variables in a study of cow level risk factors for the loser cow state in Danish dairy herds. The variables marked with * are quantitative, the rest of the variables are qualitative.

Variable	Description/levels
Parity	Parity at the time of examination: 1, 2 or 3 or older
Month for last calving	January, February, ...,December
Course of last calving	Easy: no or only minimal help Difficult: Requiring help from farmer, veterinarian or caesarean section
Purchase status	No purchase: Born in the herd Early purchase: Purchased more than 10 weeks before first calving Intermediate purchase: Purchased between 10 weeks before first calving and first calving Late purchase: Purchased after first calving
Height*	Height measured during the first lactation and adjusted for time from calving (cm)
Breeding value for milk production*	0.5*(breeding value for milk $production_{dam}$ + breeding value for milk $production_{sire}$)
Age at first calving*	Age in days

Results

Descriptive characteristics of the 39 herds included in the study are presented in Table 2. The result of the correspondence analysis is presented in Figure 1. The first two dimensions which are presented in Figure 1 accounted for 23.4 % (12.3% and 11.1 %, respectively) of the spatial variation in the data. The variables that had the highest partial contributions to the inertia were organic herds (0.12), no grazing (0.12) and a high number of cows per cubicle (0.10) for dimension 1 and a low average milk yield (0.14), a low mortality among the calves (0.12) and a high bacterial count in milk (0.12) for dimension 2. A high proportion of loser cows seems to be associated with a high proportion of stillborn calves, a high calf mortality, a high average somatic cell count and no grazing. A low proportion of loser cows on the other hand seems to be associated with the use of grazing, intermediate somatic cell count, a low proportion of stillborn calves and small herds. None of the active variables seemed to be so closely associated that only one of them was included in the subsequent analysis of the unconditional associations between the potential risk factors and the proportion of loser cows in the herds.

Next page: Figure 1. Plot of correspondence analysis results from a Danish study of risk factors for the loser cow state. Both explanatory variables and the outcome are plotted on the first two dimensions of the correspondence analysis.
SCC: Somatic cell count; **int.**: Intermediate; **feed.**: Number of cows per feeding place; **cub.**: Number of cows per cubicle; **bact.**: Bacterial count in milk; **mort.**: mortality.



Low yield
Many stillborn
High bact.
High feed.
Organic
Many loser cows
High SCC
High calf mort.
Int. calf mort.
Low feed.
Int. herd
No grazing
High yield
Increasing herd size
Old farmer
Middleaged farmer
Low cub
Large herd
Soft cubicles
Hard cubicles
Int. SCC
High cub.
Int. cub.
Int. stillborn
Grazing
Unchanged herd size
No loser cows
Conventional
Few loser cows
Int. bact.
Young farmer
Small herd
Int. yield
Low SCC
Int. feed.
Few stillborn
Low bact.
Low calf mort.

The number of cows per feeding place, average milk yield and the farmer's experience had p-values over 0.1 (0.17, 0.14 and 0.14, respectively) in the analysis of the unconditional associations between the potential risk factors and the proportion of loser cows in the herds and were thus not included in the subsequent analysis.

The final logistic regression model at the herd level included the explanatory variables stall surface, use of grazing and average somatic cell count in the herd. Statistically significant interaction was found only between stall surface and the use of grazing (p=0.023). Whenever an interaction turns out to be significant the main effects of the constituent terms are likely to be misleading. Therefore, the main effects of stall surface and use of grazing were removed from the model (Woodward, 1999). The results of the logistic regression at the herd level are presented in Table 4. The relationship between the quantitative explanatory variables and the outcome (logit (p)) was approximately linear for all the quantitative explanatory variables and they were therefore included in the model as quantitative variables. This way we did not throw away any information in the data by categorising continuous variables (Dohoo et al., 2003). We evaluated the variable 'organic or conventional herd' as a possible confounder for stall surface and use of grazing. The odds ratios for stall surface and use of grazing changed only minimally with and without 'organic or conventional herd' included in the model. We therefore concluded that 'organic or conventional herd' was not a biologically relevant confounder. The overdispersion parameter, the Pearson χ^2 test, the deviance χ^2 test and the Hosmer-Lemeshow goodness-of-fit test all indicated acceptable overall fit of the model.

Table 4. The final logistic regression model in a study of herd level risk factors for loser cows in 39 Danish dairy cattle herds.

Variable	Level	OR	95 % CI	p-value
Average somatic cell count		1.81#	1.37-2.39#	<0.0001
Stall surface * use of grazing	Soft cubicles and grazing	0.09	0.04-0.23	<0.0001
	Hard cubicles and grazing	0.45	0.30-0.69	
	Soft cubicles and no grazing	0.78	0.38-1.61	
	Hard cubicles and no grazing	1		

#: For an increase in average somatic cell count of 100,000 cells per ml
OR: odds ratio; 95 % CI: 95 % confidence interval for OR

The results of the logistic regression at the cow level is presented in Table 5. The final model included parity as an explanatory variable. Odds ratio for the loser cow state increased significantly with increasing parity. Additionally, height and breeding value for milk production had p-values over 0.05, but below 0.15. They are therefore also presented in Table 5. There was a tendency for higher odds ratio for the loser cow state with increasing height and lower odds ratio with increasing breeding value for milk production. The relationship between the quantitative explanatory variables and the outcome (logit (p)) was approximately linear for all the quantitative explanatory variables and they were therefore included in the model as quantitative variables. We found no statistically significant interactions and no biologically relevant confounding. The Hosmer-Lemeshow goodness-of-fit test indicated acceptable overall fit of the model.

Table 5. The final logistic regression model in a study of cow level risk factors for loser cows including 6,451 cows from 39 Danish dairy cattle herds.

Variable	Level	OR	95 % CI	p-value
Parity	1	0.16	0.10-0.26	0.0036
	2	0.41	0.27-0.62	
	3 or older	1		
Height		1.20§	0.92-1.57§	0.1245
Breeding value for milk production		0.76#	0.60-0.97#	0.0632

§: For an increase in height of 5 cm
#: For an increase in breeding value for milk production of 5 units
OR: odds ratio; 95 % CI: 95 % confidence interval for OR

Discussion

Correspondence analysis can provide insight into how explanatory variables are related to each other and how groups of explanatory variables are related to the outcome of interest. However, correspondence analysis does not quantify the effect of the explanatory variables on the outcome nor does it allow for the detection and evaluation of confounding or interaction. Therefore, correspondence analysis should be used in conjunction with other unconditional or multivariable analyses (e.g. logistic regression) (Dohoo et al., 1996, Vaarst and Enevoldsen, 1997, Dohoo et al., 2003). In our study, the correspondence analysis did not result in any of the initial explanatory variables not being included in the subsequent unconditional or multivariable analysis. Nevertheless, we find the correspondence analysis valuable as a descriptive presentation of the associations between the explanatory variables and the outcome.

Generally, the odds ratios estimated in a population averaged model tends to be closer to 1 than odds ratios estimated in a subject specific model (Hosmer and Lemeshow, 2000, Dohoo et al., 2003). Nevertheless, we found population averaged modelling appropriate in the present setting as it estimates the effect of a risk factor across all herds. Compared to subject specific modelling interest has shifted from the individual herd to effects across herds.

The term 'risk factor' might be somewhat ambiguous. We have used risk factor to denote a factor that is statistically associated with the outcome of interest, whether or not causality has been demonstrated (Toma et al., 1999).

The results from the correspondence analysis and the logistic regression at the herd level indicated that herds with a high average somatic cell count, a high calf mortality, many stillborn calves, hard cubicles and no grazing in general had many loser cows. We believe that the average somatic cell count, the calf mortality and the proportion of stillborn calves are indicators of the management level in the herd. The influence of management style on production, disease and culling has been described by several authors (e. g. King, 1981; Dohoo et al., 1984; Bigras-Poulin et al., 1985a; Bigras-Poulin et al., 1985b; Faye, 1991; Beaudeau et al., 1996; Barkema et al., 1999). Barkema et al. (1999) studied management style in 300 Dutch dairy cattle herds. They identified two groups of farmers described as 'clean and accurate' and 'quick and dirty', respectively. The 'clean and accurate' farmers were characterised by having a low bulk milk somatic cell count. The association between management factors and calf mortality/stillborn calves has been investigated by e.g. Jenny et al. (1981), Waltner-Toews et al. (1986) and Lance et al. (1992). We find it plausible that the association between the average somatic cell count, the calf mortality, the proportion of stillborn calves and the proportion of loser cows in the herd is caused by general management factors. A farmer that is able to produce milk with a low average somatic cell count and keep mortality among the calves at a low level also seems to be able to keep problems with loser cows at a low level. Many loser cows die or are euthanised (Thomsen et al., 2005b). The dead cows therefore might be considered as 'the top of the iceberg' regarding the loser cows. Thomsen et al. (2005a) concluded that a high somatic cell count at the herd level was a risk factor for dairy cow mortality.

We have demonstrated an association between soft cubicles, the use of grazing and a low proportion of loser cows at the herd level. Several studies have demonstrated the association between a soft stall surface and few lesions on the legs of the cows and a low prevalence of lameness (e.g. Weary and Taszkun, 2000; Wechsler et al., 2000; Vokey et al., 2001; Livesey et al., 2002; Webster, 2002; Cook et al., 2004). Alban and Agger (1996) concluded that grazing is associated with better health and Gustafson (1993) concluded that health in general was significantly influenced by exercise, reducing the frequency of veterinary treatment. Regula et al. (2004) concluded that loose-housing and regular outdoor exercise had several positive effects on the health and well-being of dairy cows.

Thomsen et al. (2004) concluded that mortality risk was significantly higher among older Danish dairy cows (parity 3 or older) than among younger cows. Faye and Perochon (1995) also found a higher mortality among older cows. The incidence of numerous diseases increases with increasing age (parity) of the cow (e.g. Rowlands et al. 1985; Erb and Gröhn, 1988; Gröhn et al., 1998; Weary and Taszkun, 2000). It is therefore not surprising that we found an increase in the odds ratio for the loser cow state with increasing parity.

The relationship between milk production level and health has been the matter of much debate (see e.g. reviews by Rauw et al. (1998) and Ingvartsen et al. (2003)). Even though not statistically significant we found a tendency for a decrease in the odds ratio for the loser cow state with increasing breeding value for milk production. This finding does not support the assumption that increased milk yield is associated with negative effects on health.

We also found a tendency for an increase in the odds ratio for the loser cow state with increasing height of the cow. The explanation behind this finding might be that the largest cows do not 'fit' the size of the cubicles. The cubicle partitions therefore physically damage the cows. Mahoney et al. (1986) concluded that small cows have fewer health problems than large cows and Hansen et al. (1999) found a longer productive life for small cows and fewer small cows culled because of problems with legs and feet.

One of the major objectives of our study were to identify risk factors that could be used as the basis of advice aimed at reducing the proportion of loser cows in a herd. Ideally, these risk factors should have a relatively large impact on the predicted risk for the loser cow state. Additionally, the farmer should be able to change the risk factors without too much work or extra costs relative to the benefits. The risk factors we have shown to have a significant effect on the odds ratio for the loser cow state all have a relatively large impact on the predicted risk for the loser cow state, but in general the farmers will not be able to change them easily. In general, it is easier for the farmer to make changes regarding management (e.g. increase the intensity of oestrus detection among heifers to reduce the age at first calving) than changes regarding the physical facilities of the farm (e.g. stall surface or herd size).

Conclusions

Danish dairy herds with a high average somatic cell count, a high calf mortality, many stillborn calves, hard cubicles and no grazing seem to be associated with a high proportion of loser cows. At the cow level odds ratio for the loser cow state increases significantly with increasing parity.

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10. General discussion and perspectives

Mortality among Danish dairy cows has increased considerably from 1990 to 2001. We concluded that this increase might for a great part be explained by an increasing number of euthanised cows. An increase in the number of cows dying unassisted constitutes an animal welfare problem (suffering before death). The situation concerning euthanised cows is more complex. An increase in the number of euthanised cows might be due to an increase in the number of seriously ill cows. This situation also has negative impacts on animal welfare. If, on the other hand, the increase in the number of euthanised cows is not a consequence of increased morbidity, but caused by an altered threshold for euthanasia among farmers, it might have a positive impact on animal welfare. More seriously ill cows might be euthanised and thus not put through a (perhaps long) period of suffering associated with disease and treatment. Euthanasia in itself is not an animal welfare problem, if it is performed quickly and without suffering for the cow. However, Thomsen et al. (2004) have shown that the majority of Danish cows and calves shot (penetrating captive bolt) were not exsanguinated subsequent to shooting. This situation constitutes a problem both legally and in relation to animal welfare as exsanguination subsequent to shooting is needed to ensure the death of the animal (Anon., 1994; Grandin, 2002).

At the start of the project three requirements regarding the relevance of the concept of loser cows were formulated. The concept of loser cows were to be regarded as relevant if 1) the prevalence of loser cows was sufficiently high to be of practical relevance, 2) the loser cow state had negative consequences for the cow and/or the farmer, and 3) the concept of loser cows was different from already known clinical entities. If the prevalence of loser cows is very low, the problem may be regarded as small and of no practical relevance. If the loser cow state has no negative consequences for neither the cow nor the farmer, neither the cow nor the farmer would benefit from a reduction of the problem. Last, but not least, if a loser cow was in fact just another way of describing e.g. a lame cow, the concept of loser cows would be of no relevance. We have shown that the prevalence of loser cows in Danish dairy herds with loose-housing systems is relatively high (the overall prevalence being over 3 %). The negative consequences of being a loser cow are relatively large concerning both milk production, mortality, culling, morbidity and workload for the farmer. Furthermore, we have demonstrated that a loser cow is different from, and more than just, a lame cow. The loser cow state therefore is considered a relevant concept.

‘Prevention is better than cure’ has been a dogma in both human and veterinary medicine for many years (e.g. Peters and Tschischkale, 2004; Anon., 2005). Additionally, when it comes to many loser cows, cure seems rather futile. Therefore, prevention seems to be the right way of dealing with loser cows. One of the objectives of this project was to identify risk factors that could be used as the basis of advice aimed at reducing the proportion of loser cows in a herd. Ideally, these risk factors should have a relatively large impact on the predicted risk for the loser cow state. Additionally, the farmer should be able to change the risk factors without too much work or extra costs relative to the benefits. The risk factors where we found a significant effect on the odds ratio for the loser cow state all had a relatively large impact on the predicted risk for the loser cow state, but in general the farmers will not be able to change them easily. The parity distribution of the cows in the herd, the stall surface or the use of grazing are not easily changed. If e.g. age at first calving had a significant effect on the predicted risk for the loser cow state, the farmer could (without too much extra work or extra costs) start oestrus detection and insemination at a younger age, and thereby reduce the age at first calving. We found relatively few risk factors with a statistically significant effect on the occurrence of loser cows. This might be because the number of loser cows included in the analysis was relatively small. Additionally, we did not have any information on a number of potential risk factors (e.g. the occurrence of diseases during early life) and were therefore not able to evaluate the effect of these potential risk factors. Future research might identify additional risk factors that might have a larger potential as a basis for advice.

The loser cow score and - even more so - the simple loser cow score are relatively quick and easy to use. Scoring of 40 – 50 cows in one hour by an observer with only a limited amount of training is realistic. It is therefore conceivable that the simple loser cow score might be a useful tool in commercial dairy herds in the future. Advisors, veterinarians or even the farmers themselves may use the loser cow score to identify potential loser cows. This information might be utilised by the farmer when he/she has to decide which cows to cull in the near future. A cow with a high loser cow score is probably at a higher risk of causing trouble in terms of morbidity, extra workload, death etc. The farmer therefore may want to cull cows with a high loser cow score as soon as possible. Sometimes a farmer wants to keep a cow even if she is at high risk of causing trouble in the future. The cow might be in an advanced stage of pregnancy or the farmer might want to keep her for breeding purposes. In these cases the loser cow score might be used as a management tool. The farmer should monitor cows with a high loser cow score intensively. If needed, special care (e.g. moving the cow to a pen with deep litter) should be instituted, thereby hopefully helping the cow remain a productive member of the herd.

These potential uses of the loser cow score need to be evaluated scientifically. Further areas for future research include e.g. identification of additional risk factors for the loser cow state and an evaluation of the effect on the prevalence of loser cows of housing systems with several groups of cows. A system where 'weak' cows are housed separately might benefit these cows and reduce the prevalence of loser cows. These groups of 'weak' cows might include young cows (parity 1) and/or cows in the start of the lactation (e.g. 0 – 30 days p.p.). An evaluation of the behavioural characteristics of loser cows also would be interesting. How does the loser cow score (physical characteristics) affect the behaviour of the cow? Are loser cows generally having low social rank in a flock of cows?

We have demonstrated that loser cows have significant negative consequences for the cow and for the farmer. Hopefully, one or more of the approaches mentioned above will be useful in reducing the prevalence of loser cows in the future. McDowell and Newell (1987) states that the development of a score in itself may influence the prevalence of the disease that the score was designed to measure. The development of a score focuses attention on the problem, and the resulting intervention (if successful) will tend to reduce the prevalence of the problem, in turn reducing the value of the score. Hopefully, the loser cow score will 'render itself unnecessary' some time in the future.

Once a loser cow, always a loser cow? This question still remains to be answered. The time course of the loser cow state and the possibilities of recovery has not been evaluated during this project. However, preliminary results indicate that approximately 65 % of cows scored more than once receive loser cow scores that differ only 1 point or less between the two scorings. Further research is needed in this area. The data for such an evaluation already exist, as our study was designed to enable us to evaluate these questions.

During the course of the project the question: 'Are loser cows in fact a 'product' of the increasing industrialisation of the dairy production?' have often been asked by farmers, journalists and others.

As mentioned in the introduction, the debate about loser cows has started at the same time as the Danish dairy industry has undergone dramatic structural changes. However, two things happening at the same time naturally does not mean that these things are causally related. At present a precise answer to the question cannot be given. It is possible that decreased attention to the individual cow in large herds (King, 1981; Dohoo et al., 1984; Nørgaard et al., 1999) may increase the prevalence of loser cows. If the farmer does not pay adequate attention to the individual cow, the risk of the cow becoming a loser cow may increase. If a lame cow is identified relatively quickly after the onset of lameness, hoof trimming, medical treatment and/or transfer to a pen with deep litter may cure the cow. If the lame cow, on the other hand, is not identified, she might become chronically lame. She will then have trouble lying down and getting up, the risk of physical injuries from the physical environment in the stable increases (Winckler et al., 2003), the pain associated with walking will cause her to be less active and eat and drink less often (O'Callaghan et al., 2003), she will be prone to displacement from the feed bunk by other cows and so on (Endres et al., 2005). We have shown that the mortality risk at the herd level increases with increasing herd size. Smith et al. (2000) found increasing mortality rates with increasing herd size among dairy cattle herds in the eastern part of the United States. However, no significant relation between percentage of dead cows and herd size was found in Canadian herds (Batra et al., 1971). We found no statistically significant effect of herd size on the proportion of loser cows in the herd. This might be because there is no association between herd size and the proportion of loser cows. It might also be because the number of herds included in the study was relatively small or because all the herds in the study were relatively large (more than 100 cows). The difference in the amount of attention paid to individual cows is probably larger when comparing a herd with 40 cows and a herd with 120 cows than when comparing a herd with 120 cows and a herd with 360 cows. Even though not statistically significant we found a tendency for a decrease in the odds ratio for the loser cow state with increasing breeding value for milk production. This finding does not support the assumption that increased milk yield is associated with negative effects on health. In conclusion, a precise answer to the question: 'Are loser cows in fact a 'product' of the increasing industrialisation of the dairy production?' is not possible at the moment. Future research may give the answer.

We have studied loser cows in herds with loose-housing systems only. The definition of a loser cow does not restrict the concept of loser cows to any particular housing system. Nevertheless, it is conceivable that the problems with loser cows may be larger in loose-housing systems compared to tie stalls. Generally, the individual cow often receives a larger amount of attention in tie stalls. A decrease in the feed intake is often the first indication of disease. In tie stalls the amount of feed eaten by the individual cow can be closely monitored by the farmer. Therefore, the farmer might generally become aware of sick cows at an earlier stage of disease in tie stalls. The demands on the cow in terms of mobility are generally larger in loose-housing systems. Additionally, the competition for resources (feed, water and resting places) among the cows may be a problem in loose-housing systems.

Management undoubtedly has a profound impact on the general health among a group of cows (e.g. King, 1981; Enevoldsen and Gröhn, 1996; Regula et al., 2004), but management is very difficult to 'measure' (e.g. Goodger et al., 1981; Brand et al., 1996; Barkema et al., 1999). 'Good management' undoubtedly plays a very important role in keeping the cow mortality and the number of loser cows in a dairy herd low. Variables describing management has been included in the evaluation of risk factors for both cow mortality and loser cows. Additionally, the impact of management on the prevalence of loser cows is currently being studied in a subset of the herds in the study based on qualitative research interviews. This research might produce new knowledge about the associations between problems with loser cows and management.

Not everything that is countable counts, and not all that counts is countable
Albert Einstein

11. Conclusions

Mortality risk among Danish dairy cows has increased from approximately 2 % in 1990 to approximately 3.5 % in 1999. Mortality risk has increased for all age groups over the years, but the mortality risk among older cows (parity 3 or older) is approximately twice the mortality risk among younger cows. A high proportion of deaths occur during the first 30 days of the lactation. Replies from a questionnaire survey has shown that 58 % of the dead cows were euthanised and 42 % died unassisted. Furthermore, the replies indicated that the proportion of euthanised cows had increased. More than half of the farmers stated that they euthanised relatively more cows in 2002 than five years earlier.

Mortality risk at the herd level varied considerably among herds. Some herds had a low mortality whereas others had a very high mortality. In total, 27 % of the herds had no dead cows during the year studied, whereas more than 10 % of the herds had a mortality risk during the first 100 days of the lactation exceeding 5 %.

A number of herd level risk factors for cow mortality was identified. Mortality risk at the herd level increased with increasing herd size, increasing proportion of purchased cows, and increasing average somatic cell count at the herd level. Mortality risk decreased with increasing average milk yield per cow. The risk was low in free stall barns with deep litter compared to those with cubicles and tie stall barns. Herds comprising Danish Holstein or Danish Jersey as the predominant breed had a higher mortality risk than those comprising Danish Red Dairy Breed. Mortality risk was lower in organic herds compared to conventional herds and in herds that were pasture grazed during the summer. The risk factors all had a relatively large effect on the predicted mortality risk in the herd.

A **loser cow** has been defined on the basis of a clinical examination of the individual cow. The observations from the clinical examination were converted into a loser cow score. A total of 15,151 cows from 39 commercial dairy herds were assigned a loser cow score. Cows with a loser cow score of 8 or more were classified as loser cows. Using this definition, we found an overall prevalence of loser cows of 3.24 %. The loser cow state has a number of negative consequences for the farmer and for the cow. Loser cows has decreased milk production and increased mortality and morbidity compared to non loser cows. Loser cows are more often than non loser cows culled in an 'unfavourable way' and the farmers generally assessed that the loser cows caused an increased workload compared to non loser cows.

The relation between the new 'diagnosis' loser cow and lameness was evaluated and it was concluded that a loser cow is different from, and more than just, a lame cow.

Risk factors for loser cows were evaluated both at the cow level and at the herd level. Herds with a high average somatic cell count, a high calf mortality, many stillborn calves, hard cubicles and no grazing seem to be associated with a high proportion of loser cows. Additionally, older cows seem to be at greater risk than younger cows.

The loser cow score (and in particular a simplified version of the loser cow score) is relatively quick and easy to use. Therefore, these scores may be used both in research and in clinical practice in the future.

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Appendix 1 – clinical protocol

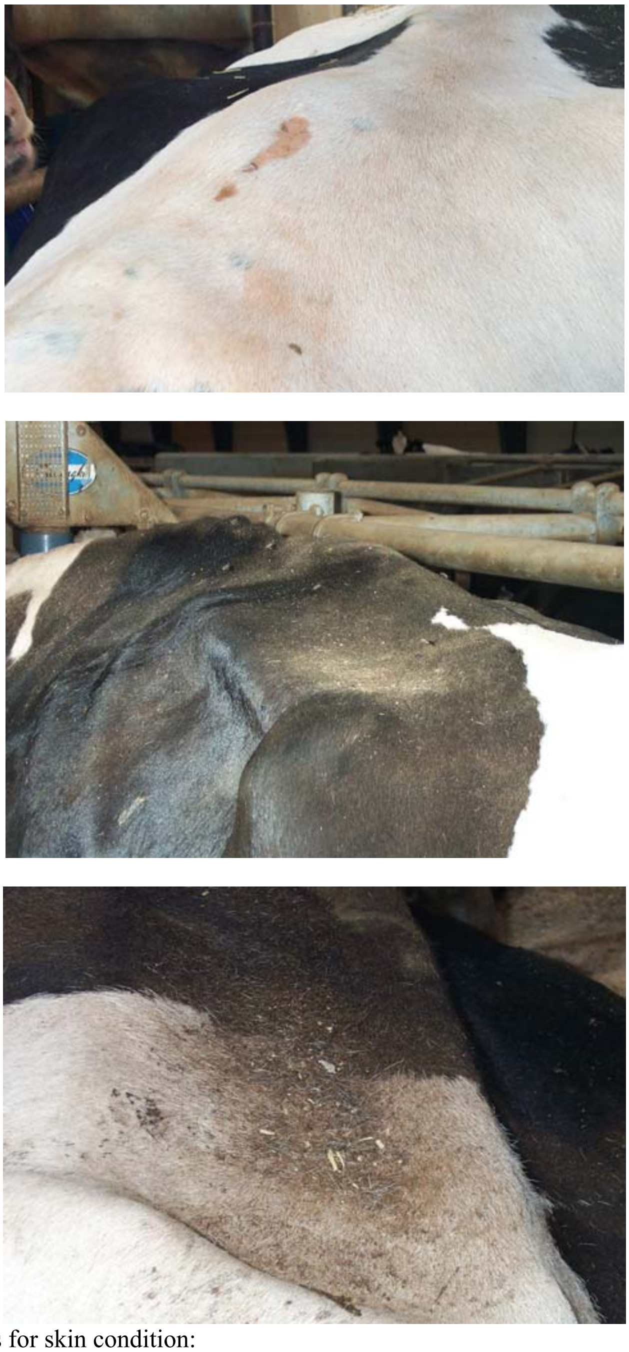
Clinical sign	Scores
Lameness (from Sprecher et al., 1997)	**1**: Normal: The cow stands and walks with a level-back posture. Her gait is normal. **2**: Mildly lame: The cow stands with a level-back posture but develops an arched-back posture while walking. Her gait remains normal. **3**: Moderately lame: An arched-back posture is evident both while standing and walking. Her gait is affected and is best described as short-striding with one or more limbs. **4**: Lame: An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favours one or more limbs/feet. **5**: Severely lame: The cow additionally demonstrates an inability or extreme reluctance to bear weight on one or more of her limbs/feet.
Body condition score (BCS) (modified after Ferguson et al., 1994)	**1**: Fat: BCS >= 4. **2**: Normal: 2.25<=BCS<=3.75. **3**: Thin: 1.5<=BCS<=2. **4**: Emaciated: BCS<=1.25
Hock lesions (only the most severe lesion found is scored)	**1**: No hock lesions: no contusions or abscesses, no hair loss, no thickening of the skin. **2**: Hair loss and/or slight thickening of the skin and/or wounds <= 2 cm in diameter. **3**: Hyperkeratosis and swelling of the skin and/or fluid filled bursae and/or larger wounds (>2 cm in diameter). **4**: Larger swellings with hyperkeratosis and fluid filled bursae and/or abscesses. Wounds may be present. Suppurative lesions and lesions affecting the hock joint and/or bones may be present.
Other cutaneous lesions (hips, neck, ribs, legs, back or other parts of the body besides hocks) (only the most severe lesion found is scored)	**1**: No lesions: no contusions or abscesses, no hair loss, no thickening of the skin. **2**: Hair loss and/or slight thickening of the skin and/or wounds <= 2 cm in diameter. **3**: Hyperkeratosis and swelling of the skin and/or fluid filled bursae and/or larger wounds (>2 cm in diameter). **4**: Larger swellings with hyperkeratosis and fluid filled bursae and/or abscesses. Wounds may be present. Suppurative lesions and lesions affecting joints and/or bones may be present.

Vaginal discharge	**1**: No vaginal discharge. **2**: Vaginal discharge seen from the vagina and/or on the tail and/or perineum.
Skin condition	**1**: Skin shiny, no or only a little dust on the back. **2**: Skin dull, dust on the back of the cow. **3**: Skin very dull, much dust on the back, a general impression of a cow not cleaning herself.
General condition	**1**: Undisturbed general condition. **2**: Slightly disturbed general condition, slight dullness, slightly depressed **3**: Disturbed general condition, very dull, depressed, grinding of teeth might occur.

Photos of examples of scores for hock lesions, other cutaneous lesions and skin condition are presented on the next pages.

Examples of scores for hock lesions:
Top left: Score 1. No hock lesions.
Top right: Score 2. Hair loss.
Bottom left: Score 3. Hyperkeratosis, swelling of the skin and a small wound.
Bottom right: Score 4. Larger swelling (abscess with hyperkeratosis and wound).

Examples of scores for other cutaneous lesions:
Top left: Score 1. No lesions.
Top right: Score 2. Hair loss.
Bottom left: Score 3. Hyperkeratosis, swelling of the skin and a small wound.
Bottom right: Score 4. Abscess with hyperkeratosis and a large wound.



Examples of scores for skin condition:
Top: Score 1. Skin shiny, no or only a little dust on the back. *Middle:* Score 2. Skin dull, dust on the back of the cow. *Bottom:* Score 2. Skin very dull, much dust on the back.

Summary

During the last few years Danish dairy farmers have expressed increasing concerns about a group of cows, which we have chosen to term 'loser cows'. A loser cow is for different reasons not able 'to keep up with' the rest of the cows in the herd.

Many loser cows die or are euthanised. The dead cows are therefore considered as some sort of 'top of the iceberg' considering the loser cows. Mortality among Danish dairy cows is described in detail in this PhD Thesis.

A loser cow is defined based on a clinical examination of the individual cow. The consequences of the loser cow state on production, morbidity and mortality are evaluated. Risk factors for the loser cow state are evaluated and prevention and handling of loser cows is discussed.

Plant production	Horticulture	Livestock