Associations of Type of Loose-Housing and Breed of Cow with Health, Milk Yield and Fertility

Associations of Type of Loose-Housing and Breed of Cow with Health, Milk Yield and Fertility

ACADEMIC DISSERTATION

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SECTION OF ANIMAL HYGIENE
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Deus vaccam, Frisii frisios fecerunt.

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My PhD thesis reminds me very much of a cow house: a great many factors influenced the results, most of them interacting in multiple ways, a few of them unreplaceable — but lacking any of these, it just wouldn't have been my thesis.

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Abbreviations

bST	Bovine somatotropin
CLH	Cold loose-housing system
DIM	Days in Milk (time from calving)
EU	European Union
FABA	Finnish Animal Breeding Association
LIR	Lactational incidence risk
OIE	World Organization for Animal Health
WLH	Warm loose-housing system

Abstract

Finnish dairy farmers are exploring several management strategies to advance the objectives of the European Union Common Agricultural Policy. One strategy is production in a cold loose-housing system (CLH, a system in which the climatic conditions inside the barn are similar to conditions outside) — in 1997, about 40 farms were using a CLH. A second management strategy is changing from the more traditional Finnish Ayrshire breed to the more modern Finnish Black and White breed — in 2000, about 25% of Finland's dairy cows were Finnish Black and White. Implementation of these strategies may be related to changes in incidences of diseases, with severe consequences for farm economy and/or welfare of the cow, as well as to changes in milk yield and fertility of the cow. In this thesis, effects of both strategies on cows' health and effects of type of loose-housing on cows' milk yield and fertility were studied. For comparison, effects of the more traditional warm loose-housing systems (WLH) and the Finnish Ayrshire breed were used.

The thesis is composed of four different retrospective observational cohort studies. To estimate the effect of type of loose-housing on cows' health, milk yield and fertility, 2630 cows in 168 WLH and 501 cows in 40 CLH were followed up from the beginning of 1996 to the end of 1997. To study the effect of cows' breed, about 100000 cows from approximately 6000 farms were followed up from calving in 2000 to the end of their lactation. The response variables were the cows' incidence of mastitis, parturient paresis, ketosis, ovarian disorders and metritis; the cows' milk yield on any of up to ten test-days spaced 30 days apart; the time from calving to first service; the first-service-conception risk; and the repeated-service-conception hazard. Potential confounders were the cows' parity, calving season and breed (in the studies on the effect of the type of loose-housing), and several of the farmer's management strategies and equipment. In the study on the effect of cows' breed, the study population was stratified by housing type (loose-housing and tie-stall). Statistical analysis used linear regression, Poisson analysis, logistic regression and survival analysis. In all models except the model for the repeated-service-conception hazard, correlations between cows of the same farm and test-days of the same cows were included — either in some kind of random effect term or in an extra-correlation structure.

In the study on the effect of type of loose-housing, I could not show a significant difference for any of the diseases other than metritis in Finnish Black and White cows; compared with Finnish Black and White cows in WLHs, Finnish Black and White cows in CLHs had less metritis. Similarly, I could not show a significant difference in milk yield between cows in CLH and WLH. Finally, I did show a significant 6% lower first-service-conception risk of cows in CLH, but could not demonstrate a different time from calving to first service or a different repeated-service-conception hazard. In the study on the effect of cows' breed, I showed a significantly higher risk for Finnish Black and White cows for all studied diseases except ovarian disorders; ovarian disorders were observed more often in Finnish Ayrshire cows.

The estimated differences in health, milk yield and fertility between cows kept in either of the two types of loose-housing might indicate some small problems for cows in a CLH, probably with the energy balance. Nevertheless, the differences (if they are real) are most probably so low that they should not be of concern to the farmer or any third party involved in Finland's dairy production. The estimated difference in the health between cows of the Finnish Ayrshire breed and the Finnish Black and White breed is more problematic. While thanks to the generally low incidence of diseases, the single farmer likely needs not be concerned, the large number of cows that are 'exposed' to the Finnish Black and White genes should make the breeding companies re-think their breeding strategies.

List of original publications

This thesis is based on the following original articles referred to in the text by Roman numerals I to IV:

I Schnier, C., Hielm, S. and Saloniemi, H. S., (2002). Comparison of the disease incidences of dairy cows kept in cold and warm loose-housing systems. *Preventive Veterinary Medicine* 53, 247–261.

II Schnier, C., Hielm, S. and Saloniemi, H. S., (2003). Comparison of milk production of dairy cows kept in cold and warm loose-housing systems. *Preventive Veterinary Medicine* 61, 295–307.

III Schnier, C., Hielm, S. and Saloniemi, H. S., (2004). Comparison of the breeding performance of cows in cold and warm loose-housing systems in Finland. *Preventive Veterinary Medicine* 62, 135–151.

IV Schnier, C., Hielm, S. and Saloniemi, H. S., (2004). Comparison of the disease incidences of Finnish Ayrshire and Finnish Black and White dairy cows. *Preventive Veterinary Medicine* 62, 285–298.

1 Introduction and review

1.1 Optimal dairy production

Objectives of the European Union Common Agricultural Policy are:

- a competitive agricultural sector,
- production methods that support environmentally friendly, quality products that the public wants,
- a fair standard of living and income stability for the agricultural community,
- diversity in forms of agriculture,
- maintenance of visual amenities and support for rural communities,
- simplicity in agriculture and sharing of responsibilities among Commission and member states and
- justification of support through the provision of services that the public expects farmers to provide

(EU Mid-term review, Brussels, 10 July 2002).

Translated into dairy production, the objectives might read: an economically sound production of high-quality milk and milk products, produced sustainably with high standards of animal welfare[1] in a (traditional?) national-romantic setting. The optimal dairy farm in this respect is one where the cow, at low financial and environmental cost, is supplied with the necessary feed, shelter, health support, and the possibility to express normal patterns of behaviour with freedom from fear[2]. The optimal dairy cow is a healthy,

[1] Interestingly enough, welfare is not explicitly mentioned in the objectives, but included in the 'production methods . . . that the public wants'.

[2] This is a short form of the 'five freedoms' in animal husbandry, first introduced by the Brambell Committee in 1965 (Webster, 1994).

contented and long-lived (traditional?) cow that can convert the locally available feed with a high conversion ratio into high-quality milk and offspring. It should go without saying (but it does not) that a single characteristic of a farm or a cow (say, milk yield) cannot be evaluated on its own, but can only be evaluated in the context of the other objectives — compared to a cow with low milk yield a cow with higher milk yield is 'optimal' only when the other objectives (health, welfare, fertility and food conversion ratio, to name a few) are not compromised.

Two different production strategies have recently been introduced by Finnish farmers to advance the EU's objectives: keeping cows in cold loose-housing systems and changing to a different cattle breed. But how do these new strategies affect cows' health, production and fertility?

This thesis examines the effect of type of loose-housing (cold and warm) on cows' health, milk yield and fertility and also investigates the effect of cows' breed (Finnish Ayrshire and Finnish Black and White) on their health. The following sections are short reviews of some of the main variables that affect the cows' health (Section 1.2.1), milk yield (Section 1.2.2 on page 11) and fertility (Section 1.2.3 on page 13) and of the two different production strategies (Section 1.3.1 on page 15 and Section 1.3.2 on page 16). The second part of this chapter reviews some definitions and concepts of epidemiology and statistics and introduces the methodology used to estimate the effect of the two production strategies on cows' health, production and fertility.

1.2 How optimal is Finnish dairy production?

1.2.1 Diseases

Although Finland's dairy population is almost free of diseases on the A[3] and B[4] lists of the World Organization for Animal Health (OIE), the incidences for several endemic diseases show that Finnish farms and cows are not optimal in regard to EU's objectives[5] (Table 1.1 on the next page). What

[3]Transmissible diseases that have the potential for very serious and rapid spread, irrespective of national borders, that are of serious socio-economic or public health consequence and that are of major importance in the international trade of animals and animal products.

[4]Transmissible diseases that are considered to be of socio-economic and/or public health importance within countries and that are significant in the international trade of animals and animal products.

[5]Again, EU's objectives do not support the disease free cow or farm, but a farm with lower incidences is better compared to a farm with higher incidences if none of the other objectives were compromised.

Table 1.1: Lactational incidence risks (%) of the most common diseases of Finnish Ayrshire dairy cows calving in 1993. *Source:* Rajala, 1998.

Diagnosis	LIR[1]	DIM[2]
Acute mastitis	17.0	47
Teat injury	3.4	100
Chronic mastitis	4.1	135
Parturient paresis	5.4	1
Ketosis	4.9	28
Ovarian cysts	7.3	94
Metritis	3.2	21
Lameness	2.3	52

[1](Number of first cases/Number of calvings)×100
[2]Median time in days from calving to diagnosis

most of these diseases have in common is that they have a negative impact on cows' milk production and welfare, they increase cows' risk of being culled prematurely and that their incidence can be influenced by genetic and environmental factors. Additionally, most have a subclinical state, which makes it complicated to discern healthy from diseased animals. Some of the most important endemic diseases (high prevalence and negative impact on farm's economy and cows' welfare) are mastitis, parturient paresis, ketosis, ovarian disorders and metritis.

1.2.1.1 Mastitis

Mastitis is an inflammation of one or more udder quarters of a cow, generally manifesting together with bacterial colonialization of the teat. In Finland in 1998, the bacteria cultivated from cows with clinical signs of mastitis were in approximately 19% of cases *Staphylococcus aureus*, in 36.5% coagulase-negative staphylococci, in 9% *Streptococcus uberis*, in 7% *Escherichia coli* and in 4% *Streptococcus dysgalactiae* (in 44% of cases, no bacteria could be cultivated; Saloniemi and Kulkas, 2001). Mastitis can occur at any time during lactation and the dry period (Table 1.1).

Based on clinical signs, cases of mastitis are categorized in the Finnish milk recording scheme into acute, clinical, subclinical and chronic mastitis. This categorization is rather impractical for epidemiological research because diseases of very different etiological backgrounds are classified into the same groups (e. g., clinical mastitis caused by *Escherichia coli* and clinical mastitis caused by *Staphylococcus aureus*). More practical categorizations would divide cases of mastitis by the etiological agent into mastitis of infectious or environmental origin, into mastitis caused by major or minor bacterial mastitis pathogens, or subdivide cases further by the causative agent (Barkema et al., 1999).

Consequences of the cows' contracting mastitis are certainly in conflict with the EU objectives. One consequence, at least in cases of *acute* mastitis, is reduced welfare — contracting the disease is painful for the cow (Fitzpatrick et al., 2000). Indeed, the effects of mastitis on animal welfare are so severe that a projected 15-79% increase in the incidence of mastitis in combination with an increased incidence of foot problems and injection site reactions has caused the EU and Canada to ban the use of bovine somatotropin in dairy production *for welfare reasons* (EU Business Ltd., 2000). Other consequences are reduced income of farmers due to treatment costs and reduced prices for milk with high somatic cell counts (SCC)[6]; reduced milk yield (Rajala-Schultz et al., 1999b) and fertility (Suriyasathaporn et al., 1998) and a higher risk of premature culling (Rajala-Schultz and Gröhn, 1999; Beaudeau et al., 2000) — about 35% of cows culled in 2001 were culled for udder disorders (ProAgria, 2001 (unpublished)). Because the treatments for mastitis often include antibiotics (antimicrobial agents; Saloniemi and Kulkas, 2001) an additional consequence of cows' contracting mastitis is an increase in risk of residuals from antibiotics in milk (Mc. Ewen et al., 1991) and of antibiotic-resistant bacterial strains in the environment (Poppe et al., 2001).

Although all cattle populations in the world suffer to some degree from mastitis, farms with constantly low incidences show that factors at cow- and farm-level can considerably reduce cows' risk. Indeed, a long list of factors are related to cows' risk of contracting mastitis (Table 1.2 on the next page) — almost every factor in milk production seems be correlated in one way or another. Factors affecting cows' risk of contracting mastitis have been reviewed by Bramley and Dodd (1984), Hillerton (1996), Hogan et al. (1996) and Detilleux (2002).

[6] In 1998, bulk tank milk with more than 400000 cells per millilitre (3-month geometric mean) could not be delivered to the dairy; bulk milk with less than 250000 cells per millilitre was financially rewarded (Saloniemi and Kulkas, 2001).

Table 1.2: Factors at cow- and herd-level that affect cows' risk of contracting or being treated for mastitis.

Disease	Risk factor	Reference
Udder disorders	Parity/age	Rajala and Gröhn, 1998; Bartlett et al., 2001
	Breed	Emanuelson et al., 1993; Bartlett et al., 2001
	Calving season	Allore et al., 1997; Van Dorp et al., 1999
	Climate	Bartlett et al., 1992; Barkema et al., 1999
	Other diseases	Gröhn et al., 1990b; Correa et al., 1993
	Facilities	Bakken, 1981; Barkema et al., 1999
	Feeding	Jukola, 1993; Barnouin et al., 1994
	Herd size	Bartlett et al., 1992; Barkema et al., 1998
	Milk yield (cow)	Gröhn et al., 1995; Barkema et al., 1998
	Milk yield (herd)	Lescourret et al., 1995
	Management	Barkema et al., 1998; Barkema et al., 1999

Because of the relatively high incidences, the severe consequences of contracting mastitis and the observation that several factors related to cows' environment and breed can affect risk of contracting mastitis, research into the effects of new production strategies on disease incidence is necessary with every change.

1.2.1.2 Parturient paresis

Cows with parturient paresis (milk fever, hypocalcaemia) suffer from a severe shortage of calcium in extracellular fluid. Most cows contract the disease on the first day of lactation (Table 1.1 on page 3), when the sudden large demand of calcium for lactogenesis at or around parturition depletes the blood calcium levels. Almost all cows go through some degree of hypocalcaemia around parturition, but only in a few cows is the shortage so severe that they develop clinical symptoms. These cows that do show symptoms become progressively weaker until they are unable to stand (paresis); if not treated at that point, they can easily die.

Similar to mastitis, consequences of cows' contracting parturient paresis are in conflict with EU objectives. These consequences include increased expenditures for veterinary treatments and reduced milk yield (Bigras-Puolin et al., 1990) and fertility (Suriyasathaporn et al., 1998). Additionally, a cow with parturient paresis probably is at an increased risk of culling (Beaudeau et al., 2000) and of contracting other diseases (Correa et al., 1993). Another consequence is reduced welfare; although most cows recover relatively fast after veterinary treatment, before treatment clinically diseased cows obviously suffer pain, fear and discomfort.

Numerous cow and herd factors have been correlated with incidence of parturient paresis (Table 1.3 on the next page). High-yielding dairy cows are at the highest risk of the disease (Erb, 1987), which clearly shows a contradiction within the EU objectives. The cows' breed appears to affect the risk of contracting parturient paresis (e. g., Bendixen et al., 1987a), while the effect of the environment is unclear (Erb and Gröhn, 1988). Research into risk factors in Scandinavia has been published by Bendixen et al. (1987a), Enevoldsen (1993), Kusumanti et al., (1993) and Sørensen et al. (2002).

Because of the relatively high incidence of parturient paresis, reduced welfare of affected cows and decreased income, even a small increase in incidence risk as a result of farmers' changing management strategies could contravene the farmers advancements towards the EU objective.

1.2.1.3 Ketosis

Practically all cows during early lactation go through a phase of activating more fat and ketogenic amino acids from their body reserves than they can metabolize, and as a result, ketone bodies (acetone and beta-hydroxybutyrate) accumulate. Some cows, however, accumulate ketone bodies in toxic concentrations and then show signs of inappetence, lethargy and dullness together with a drop in milk yield. These are typical clinical signs of ketosis. Due to the etiology, cows in early lactation are at the highest risk of ketosis (Table 1.1 on page 3).

Cases of ketosis are often grouped into primary and secondary ketosis or clinical and subclinical ketosis, the latter being assessed from the concentration of ketone bodies in blood or milk. The Finnish Milk Recording System

Table 1.3: Factors at cow- and herd-level that affect cows' risk of contracting or being treated for digestive disorders.

Disease	Risk factor	Reference
Parturient paresis	Parity/age	Bigras-Poulin et al., 1990; Kusumanti et al., 1993
	Breed	Bendixen et al., 1987a; Enevoldsen, 1993
	Calving season	Distl, 1991; Van Dorp et al., 1999
	Other diseases	Bigras-Puolin et al., 1990; Klerx and Smolders, 1997
	Facilities	Waage, 1985
	Feeding	Enevoldsen, 1993; Sørensen et al., 2002
	Milk yield (cow)	Erb, 1987; Gröhn et al., 1995
	Milk yield (herd)	Erb and Gröhn, 1988; Gröhn et al., 1989
	Management	Gustafson, 1993
Ketosis	Parity/age	Gröhn et al. 1984, Bendixen et al., 1987b
	Breed	Erb and Gröhn, 1988; Emanuelson et al., 1993
	Calving season	Gröhn et al. 1984, Emanuelson et al., 1993
	Other diseases	Correa et al., 1993; Klerx and Smolders, 1997
	Facilities	Empel et al., 1991; Valde et al., 1997
	Feeding	Gustafsson et al., 1995; Østergaard and Sørensen, 1998
	Milk yield (cow)	Gröhn et al., 1999
	Milk yield (herd)	Willadsen et al., 1993; Rasmussen et al., 1999

nevertheless has only one disease code for the disease. Misclassification is a large problem in these recordings: an unknown number of cows with clinical ketosis are either not detected by the herdsman or treated by herself which results in a large number of false negative recordings. Unfortunately, there might be additionally a large number of false positive recordings where the veterinarian has misdiagnosed a cow with a different disorder (Simensen et al., 1990).

The major contradictions with the EU objectives that are inflicted by ketosis are probably the economic losses due to decreased fertility (Fourichon et al., 2000), reduced milk yield (Detilleux et al., 1994; Rajala-Schultz et al., 1999a) and treatment costs. In addition, ketosis increases the risk of sequelae (Correa et al., 1993) and of culling (Beaudeau et al., 2000). While the effects of ketosis on cows' welfare have not yet been studied, judging by the clinical signs, these would be considerable.

The most researched risk factors for ketosis are feeding strategies, but a large range of other cow- and herd-level factors have been identified as well (Table 1.3 on the previous page). Studies on risk factors for ketosis in Scandinavia have been published by Gröhn et al. (1984), Bendixen et al. (1987b), Willadsen et al. (1993) and Gustafsson et al. (1995), among others.

Because the cows' risk of contracting ketosis is affected by calving season (Willadsen et al., 1993) and breed (Erb and Gröhn, 1988), because the consequences of contracting the disease are quite severe and because of the relatively high apparent incidence (the true incidence may be much higher), any change in management strategies should be followed by a new study on cows' risk of contracting ketosis.

1.2.1.4 Ovarian disorders

Follicular cysts, luteal cysts, delayed ovulation and follicle atresia are examples of ovarian disorders. Since next to reducing the cows' fertility these disorders are more or less symptom-free, they are typically diagnosed only at routine post-calving inspections or after a cow fails to show heat or to conceive. Ovarian disorders are often not treated by a veterinarian but resolve with time (Emanuelson and Oltenacu, 1994; López-Gatius et al., 2002). Estimates for the incidence of contracting ovarian disorders based on veterinary treatment data (Table 1.1 on page 3) are therefore more an indicator of reproduction management than of 'true' incidence. Similarly, estimates for the time in lactation when the cow has contracted the disease based on these data are not good indicators of when the cow has actually developed the disorder (which might have been much earlier).

No peer-reviewed literature could be found to document suffering from ovarian disorder (resulting mainly from treatment and increased culling risk); pain-reducing medicine is not typically given to cows contracting these diseases. Estimation of welfare implication is complicated, because the disease complex is very heterogenous. Nevertheless, the farmer 'suffers' considerable economic losses from longer calving intervals and treatment costs.

Epidemiological studies on risk factors for ovarian disorders are complicated because the etiology of the disorder is partly unknown, the time point of the onset of the disease is unknown and the number of untreated cases is high (by definition risk factors precede the onset of the disease). Extensive research into the effect of different risk factors for ovarian disorders in Scandinavia has been published (Gröhn et al. 1990a; Emanuelson et al. 1993) (Table 1.4 on the next page).

Because of the economic losses that come with cows' contracting ovarian disorders, and because contracting the disorder is strongly related to fertility, studies on the effects of new management strategies on cows' health and fertility should certainly include ovarian disorders — especially in studies on the effects of type of loose-housing and cows' breed since effects of calving season and cows' breed are known from the literature (e. g., Grosse Frie et al., 1984; Emanuelson et al., 1993).

1.2.1.5 Metritis

Metritis is an inflammation of the cows' uterus, which is usually accompanied by bacterial colonialization of the reproductive tract. In the Finnish Milk Recording Scheme, metritis is classified as follows: early metritis ($\leq$ 6 weeks after parturition) and late metritis ($>$ 6 weeks after parturition). Early metritis is further subdivided into acute metritis and pyometra and late metritis into acute and chronic metritis. Due to a common etiological background and problematic differential diagnosis in the field, cases of metritis, vaginitis, disturbed involution of the cervix and uterus, retained placenta and dystocia are sometimes grouped together under the metritis disease complex (Bartlett et al., 1986).

Consequences of contracting metritis are similar to those listed for mastitis. For cows these include reduced welfare from pain and discomfort

Table 1.4: Factors at cow- and herd-level, that affect cows' risk of contracting or being treated for fertility disorders.

Disease	Risk factor	Reference
Ovarian disorders	Parity/age	Distl, 1991; Rajala and Gröhn, 1990
	Breed	Oltenacu et al., 1990; Emanuelson et al., 1993
	Calving season	Faye et al., 1986; Labernia et al., 1998
	Other diseases	Bigras-Poulin et al., 1990; Correa et al., 1993
	Facilities	Oltenacu et al., 1998
	Feeding	Gearhart et al., 1990
	Milk yield (cow)	Erb, 1984; Mäntysaari et al., 1993
	Milk yield (herd)	Erb, 1987; Gröhn et al., 1990a
	Management	Bigras-Poulin et al., 1984
Metritis	Parity/age	Faye et al., 1986; Bruun et al., 2002
	Breed	Bruun et al., 2002; Emanuelson et al., 1993
	Calving season	Van Dorp, 1999; Oltenacu et al., 1990
	Other diseases	Correa et al., 1993; Kaneene et al., 1995
	Facilities	Kaneene et al., 1995; Bruun et al., 2002
	Feeding	Kaneene et al., 1995; Kaneene et al., 1997
	Herd size	Bruun et al., 2002
	Milk yield (cow)	Erb, 1987 ; Mäntysaari et al., 1993
	Milk yield (herd)	Gröhn et al., 1990a
	Management	Kaneene et al., 1995; Bruun et al., 2002

and a higher risk of getting culled (Beaudeau et al., 1995). For farmers these include financial losses due to treatment costs, decreased fertility (Sandals et al., 1979) and decreased milk yield (for early metritis, only; Rajala, 1998). From the perspective of public health, these include an increased risk of antibiotic residues in the milk (Smith et al., 2002) and antibiotic-resistant bacteria in the environment (Poppe et al., 2001).

Several variables at farm- and cow-level have been correlated with the cows' risk of contracting metritis. These mostly comprise variables affecting the calving process (e. g., calving season; van Dorp et al., 1999) (Table 1.4 on the facing page), but also include other variables such as breed (Emanuelson et al., 1993). Variables affecting cows' risk of contracting metritis in Scandinavia have been studied by Gröhn et al. (1990a), Mäntysaari et al. (1993) and Bruun et al. (2002), among others.

Because of the severe consequences of contracting metritis and the observation that several factors related to the cows' environment and breed can influence cows' risk, research into the effects of new production strategies on this disease is warranted with every change.

1.2.2 Milk yield

A healthy cow that produces high amounts of milk at low production costs is at the heart of the EU objective of a competitive agricultural sector[7]. At current production costs in Finland, the most productive cow is the one with the highest protein yield per lactation. Cows' genetic milk yield potential for protein (kg) is therefore evaluated as the single most important genetic trait by the Finnish breeding association (followed by fertility, udder health, fat yield and udder conformation; Liinamo, 2000). In regard to EU's objectives, cows' mean protein yield of 250-270 kg in Finland in 2001 (Table 1.5 on the next page) was probably suboptimal, because higher yields are possible without compromising the other objectives.

The cow with the highest possible milk yield might not, however, be the most optimal cow in terms of EU objectives. Reasons for this include reduced fertility of high-yielding cows (Suriyasathaporn et al., 1998), increased feeding costs (relatively cheap local feeds have to be replaced with expensive concentrates) and a production restriction due to the milk quota regulation (in the quota-year 1999-2000, 14 million litres of milk (0.6%) were produced

[7] Apart from EU subsidies, milk production is the single most important income of Finnish dairy farmers (Maatalouden Taloudellinen Tutkimuslaitos, 2000).

Table 1.5: Typical values for milk yield and fertility in Finnish dairy production

Variable	Breed	Estimate
Yield, kg[1]	Finnish Ayrshire	7381
	Finnish Black and White	8232
Fat,%[1]	Finnish Ayrshire	4.4
	Finnish Black and White	4.0
Protein,%[1]	Finnish Ayrshire	3.4
	Finnish Black and White	3.3
Calving interval, days[2]	Finnish Ayrshire	392
	Finnish Black and White	383
Inseminations per calving[2]	Finnish Ayrshire	1.90
	Finnish Black and White	1.76
Percentage of cows culled for infertility of all cows culled[2]		22

[1] *Source:* FABA, 2002; values for 2001

[2] *Source:* Maaseutukeskusten Liitto, 1996

in excess of the national quota, and farmers producing in excess to their milk quota were punished for every 9th litre produced and sold over quota; Maatalouden Taloudellinen Tutkimuslaitos, 2000). In addition, high-producing cows might be at a higher risk of parturient paresis (Erb, 1987) and other diseases (Rasmussen et al., 1999).

Variables affecting cows' milk yield in Scandinavia have been described by Enevoldsen et al. (1996), Rajala (1998), Østergaard and Gröhn et al. (1999) and Reksen et al. (1999) (Table 1.6 on the facing page).

Reduced milk yield or higher culling rates caused by low milk yield are in conflict with EU objectives — at least as long as they do not go hand in hand with increased health, fertility or food conversion ratio. Effects of any new management strategy on cows' milk yield should therefore be evaluated carefully.

Table 1.6: Factors at cow- and herd-level that affect cows' milk yield.

Variable	Risk factor	Reference
Milk yield	Parity/age	Bigras-Puolin et al., 1990
	Breed	Empel et al., 1991; Enevoldsen et al., 1996
	Climate	Becker et al., 1990, Arave et al., 1994
	Diseases	Bigras-Puolin et al., 1990; Rajala, 1998
	Facilities	Bockisch, 1995; Ledin and Lema, 1996
	Feeding	Gustaffson et al., 1993; Yan et al., 1998

1.2.3 Fertility

For optimal dairy production, cows must deliver one healthy calf every year (Bailie, 1982)[8]. On optimal farms, this aim is achieved with a relatively low number of inseminations per pregnancy and with treatment and/or culling of only a few cows due to infertility.

These four parameters (calving interval, number of inseminations per calving, incidence of reproductive disorders and percentage of cows culled due to infertility) are examples of ways to measure and express fertility — many other methods also exist (Fetrow et al., 1990; Esslemont, 1992). Depending on the herd situation, in Finland, every day exceeding the optimal time point of a cow being pregnant costs the farmer approximately 1-1.5 €(Taponen 2000, personal communication). Recommended values for calving interval, inseminations per calving and percentage of cows culled due to infertility in Finland are 365-375, 1.6 and <5%, respectively (Taponen 2004, personal communication). Dairy herd fertility in Finland, as judged by these parameters, is therefore certainly suboptimal (Table 1.5 on the preceding page), and considerable financial losses occur due to lower milk yield, insemination and treatment costs and premature culls.

Several variables affecting cows' fertility have been studied (Table 1.7 on the following page), including cows' breed and climate. The incidence of ovarian disorders and infections of the reproductive tract has a large negative impact; indeed, it is often a fertility problem that causes the farmer to call the veterinarian when the cow contracts any of the two disease complexes.

[8]Again, EU's objectives favor a farm with one healthy calf every year over a farm with longer calving intervals only if other objectives were not compromised.

Table 1.7: Factors at cow- and herd-level that affect the cows' fertility.

Variable	Risk Factor	Reference
Fertility	Parity/age	Erb et al., 1985; Moss et al., 2002
	Breed	Webster et al., 1997b; Reksen et al., 1999
	Calving season	Gröhn and Rajala-Schultz, 1998
	Climate	Etherington et al., 1985; Filseth, 1990
	Diseases	Suriyasathaporn et al., 1998; Fourichon et al., 2000
	Facilities	Bakken et al., 1988
	Feeding	Carlsson and Pehrson, 1993; Clark et al., 1995
	Herd size	Webster et al., 1997a
	Milk yield (cow)	Harman et al. 1996b, Suriyasathaporn et al., 1998
	Milk yield (herd)	Rajala-Schulz and Frazer, 2003

Variables affecting cows' fertility in Scandinavian countries have been investigated by Eldon et al. (1988), Ettala and Virtanen (1990), Gustafsson and Carlsson (1993), Jukola (1993), Oltenacu et al. (1998), Reksen et al. (1999) and Gröhn and Rajala-Schultz (2000).

1.3 Modification of farming systems

To advance the objectives of the EU — to increase competitiveness, product quality and animal welfare — Finnish farmers modify their farming systems. This can be seen, for example, in the large number of new buildings for dairy production that have been built in recent years: in 1999 alone, investment aid was granted to 1100 dairy production buildings (Maatalouden Taloudellinen Tutkimuslaitos, 2000). Another way to accomplish the EU objectives is to 'fit' the cow to the demands of more cost-beneficial production — either through breeding towards higher production or better health or through the choice of a more cost-effective breed. Indeed, while the total number of cows in Finland is slowly decreasing, the number of cows of the Finnish Black and White breed is steadily increasing.

1.3.1 Fitting the production system to the cow: loose-housing systems in dairy production

Probably the most important reason to build a new cow house is the cost-effectiveness of larger herd sizes — both the per-capita investment into buildings and equipment and the per-capita workload decrease with increasing herd size. To keep the total workload in bigger cow houses manageable for traditional family-owned farms, a change towards low work-intensive (often highly mechanical and investment-intensive) practices is necessary. Modern farms therefore often are loose-housing systems with parlor milking and automated off-parlor feeding (automated milking systems are currently not used in larger numbers; during the study period, none were in use in Finland). Between 2001 and 2003 approximately 1/3 of all new cow houses were loose-housing systems (Maa- ja metsätalousministeriö, 2004).

Compared with the more traditional tie-stall systems, loose-housing systems come with the advantage of better udder health (Bakken, 1981; Valde et al. 1997), lower risk of ketosis (Valde et al. 1997), lower risk of traumatic injures (Blom, 1982), better fertility (Barnouin et al., 1983; Valde et al. 1997), generally being accepted by welfare scientists as having a superior potential for high animal welfare (Anonymous, 2001). Loose-housing systems, nevertheless, come with the disadvantage of higher risk of lameness (Ernst, 1983). Within loose-housing systems, cubicle houses can be distinguished from systems with deep straw bedding, with cows confined in the latter having a higher risk of mastitis (Fregonesi and Leaver, 2001) but also a higher potential for improved animal welfare (Anonymous, 2001).

1.3.1.1 Cold and warm loose-housing systems

Based on climatic conditions inside the barn, loose-housing systems can be divided into cold and warm loose-housing systems (CLH and WLH, respectively): Loose-houses are 'cold' if the climatic conditions inside the barn can be assumed to be similar to the outside conditions throughout the year (Tuure, 1995), while loose-houses are 'warm' if the construction of the barn ensures a relatively constant inside-temperature throughout the year. CLH have the advantage over WLH of being cheaper in the building process (in 2003, median construction cost per cow-place was 2763 € in CLH and 7521 € in WLH; Maa- ja metsätalousministeriö, 2004), but have the disadvantage of higher running costs (Tuure, 1995).

Effects of the type of loose-housing on cows' milk yield, fertility and health can be divided into two categories: direct and indirect effects of the climate on the cow. Direct effects include effects of temperature, draft and humidity on cows' health (Christopherson and Young, 1986). Indirect effects include the effects of heated water on milk yield (Andersson, 1985) (heating water bowls is a frequently used precaution against frozen water bowls), bedding on mastitis incidence (Barkema et al., 1999) (CLH often use more straw and sand) and different working periods on oestrus detection by the farmer.

Research into the effect of the type of loose-housing on disease incidence, milk yield and fertility has been mainly conducted in clinical trial settings in Denmark and the Czech Republic — results of these studies were incongruent (Table 1.8 on the next page). In Finland, no research on this topic has been conducted to date.

1.3.2 Fitting the cow to the production system: different cattle breeds in dairy production

Cows of different breeds and within breeds of different genetic backgrounds show consistent breed and sire-specific traits in health, milk yield and fertility. A genetic improvement of the breed or — more dramatically — a change of the breed of the herd can therefore accomplish some of the EU objectives: superior herd health, herd fertility or milk yield.

Genetic improvement of the two most important breeds in Finland (Finnish Ayrshire and Finnish Black and White) is centrally organized by the Finnish breeding organization (FABA). Breeding goals and strategies are the same for both breeds — increased yields per lactation (especially protein) and better udder health. As part of the breeding strategies in the Ayrshire breed, semen has been imported from North America, the UK, Norway and Sweden (Finnish Ayrshirebreeders ry, 2001) to slowly change the traditional Finnish Ayrshire into a Scandinavian Red and White (Ayrshire Canada, 2000). Similarly, as part of the breeding strategies for the Finnish Black and White, semen from North American Holstein Friesians has been imported and the more-traditional Finnish Friesian has been modified to a Holstein breed (Lidauer and Mäntysaari, 1996).

The breeding strategies have been enormously successful — between 1986 and 1995, lactational yields of cows improved from 5820 to 6923 litres

Table 1.8: Results from studies investigating the effect of type of loose-housing (cold loose-housing (CLH) versus warm loose-housing (WLH)) on morbidity, production and reproduction of dairy cows. Definitions of cold and warm loose-housing systems were different in different studies.

Variable	Observations	Reference
Mastitis	Higher in CLH	Cramer et al., 1974; Konggard, 1980
	Lower in CLH	Konggard and DeDecker, 1984; Blom et al., 1985
Reproductive disorders	No difference	Thysen et al., 1985
	Lower in CLH	Konggard, 1980; Konggard and DeDecker, 1984
Metabolic disorders	No difference	Konggard, 1980; Konggard and DeDecker, 1984; Thysen et al., 1985
Milk yield	No difference	Bešlin and Anojčić, 1979; Hindhede and Thysen, 1985; Broucek et al., 1997
	Higher in CLH	Konggard, 1980; Konggard and DeDecker, 1984
Fertility	No difference	Konggard, 1980; Krohn and Rasmussen, 1992
	Better in CLH	Thysen and Hindhede, 1985
	Worse in CLH	Konggard and DeDecker, 1984

per lactation[9] (Maaseutukeskusten liitto ry, 1997). Unfortunately, though, the improved milk yield seems to be negatively correlated with several health traits (e. g., Rajala and Gröhn, 1998) and fertility parameters (e. g., Lean et al., 1989).

Comparisons of milk yield and fertility between Finnish Ayrshire and Finnish Black and White have shown that Finnish Black and White cows generally have a higher milk yield and better fertility (Table 1.5 on page 12) (Rautala, 1991). However, when health between the two breeds was compared results were controversial (Table 1.9 on the next page). The discrepant findings might be due to the speed of the breeding process or to changes in management and facilities. They might also be due to differences in the set-up of different studies (e. g., differences in study populations or in statistical analyses).

Reasons for observed differences within and between breeds are not obvious. Behavioural pattern, body conformation (e. g., a higher attached udder) or metabolism might be correlated with breed-specific health, yield and fertility. Milk yield may also be associated with differences in breed-specific disease incidences. The higher milk yield of the Finnish Black and White breed, for example, is certainly correlated with the large exterior of the Friesian cow — bigger animals have greater potential for large food intake, which is often the restricting factor in milk yield (McDonald et al., 1995). The larger exterior could also cause differences in disease incidences (Bruun et al., 2002). A different genetic make-up of the immune system might further explain differences in susceptibility towards udder pathogens (Detilleux, 2002).

Many studies in the Finnish dairy population concerning incidences of diseases or culling, milk yield or fertility have used the Finnish Ayrshire population only (e. g., Gröhn et al., 1984, Detilleux et al., 1994; Harman et al., 1996c; Rajala 1998). Because the percentage of the Finnish Black and White breed of the total Finnish dairy population has increased steadily (currently at $\approx 25\%$), this breed should also be included in research. Studies conducted by the breeding organizations already include both breeds, but normally exclude older cows and phenotypic effects, concentrating on udder health, fertility and milk yield.

[9]Impressive as these numbers are, much of the increase is not based on genetics but on improvements in feeding and dairy management. Moreover, while the total output per cow is increasing, the feed-conversion ratio is decreasing (Webster, 1993).

Table 1.9: Results of studies investigating the effect of cow breed (Ayrshire-type and Black and White type) on morbidity of dairy cows.

Disease	Black and White breed	Correlation	Ayrshire breed	Reference
Mastitis	Finnish Black and White	$>$	Finnish Ayrshire	Ettala and Virtanen, 1990; Myllys and Rautala, 1995
Tramped teats and mastitis	Swedish Friesians	$>$	Swedish Red and White	Bendixen et al., 1988a; Bendixen et al., 1988b; Emanuelson et al., 1993
Parturient paresis	Friesian breeds from other countries	$\approx$	Finnish Ayrshire	Erb and Gröhn, 1988
	Swedish Friesians	$<$	Swedish Red and White	Erb and Gröhn, 1988
Ketosis	Finnish Black and White	$<$	Finnish Ayrshire	Ettala and Virtanen, 1990
	Friesian breeds from other countries	$<$	Finnish Ayrshire	Erb and Gröhn, 1988
	Swedish Friesians	$<$	Swedish Red and White	Bendixen et al., 1987b; Emanuelson et al., 1993
Ovarian disorders	Swedish Friesians	$<$	Swedish Red and White	Emanuelson et al., 1993
	American Holstein	$\approx$	American Ayrshire	Hackett and Batra, 1985
Metritis	Swedish Friesians	$>$	Swedish Red and White	Emanuelson et al., 1993

1.4 Definitions and concepts

1.4.1 Definitions and concepts in epidemiology

Veterinary epidemiology[10] is a discipline that places animals into groups and examines, whether these divisions tell us something more than we could have learned by just observing each animal separately. It is concerned with the prevention and control of diseases in animal populations, including the investigation and assessment of other health-related events, notably productivity and welfare.

In epidemiological research, disease, productivity and welfare are often studied as effects of underlying causes. In these studies, disease, productivity and welfare are known as *response variables* (a.k.a. *dependent variables* or *outcome variables*). Some of the underlying causes (those that were used to stratify the animals into groups) are called *study variables* (a.k.a. *independent variables*[11]). The rest of the underlying causes are (potential) *confounders*, which form part of the *context*.

Response variables are often mathematically manipulated to get meaningful results in statistical analysis. Examples for manipulated response variables in veterinary epidemiological research include the cows' *risk* of getting diseased[12] (e. g., Kusumanti et al., 1993), *odds* of getting pregnant at first service (e. g., Dohoo et al., 2001), *rate* of getting diseased (incidence density; e. g., Barkema et al., 1999) and *hazard* of conception after calving (e. g., Harman et al., 1996a).

Risks and *odds* are conditional probabilities; the probabilities of a disease-free individual's developing the disease over a specified period conditional on that individual's not dying from any other disease during that period. Risk measures are typically used when the study population is stable (no entries and no losses), and only the first response is of interest. Risks, to be more specific, Lactational incidence risks (LIR), have been recommended in retrospective and current analyses for calculating the incidence of parturient paresis and retained placenta. Only in retrospective analyses have LIRs

[10] If not mentioned otherwise, definitions and concepts are taken from the following textbooks in (veterinary) epidemiology and (bio-) statistics: Kleinbaum et al. (1982), Collett (1991), Clayton and Hills (1993), Collett (1993), Giesecke (1994), Abelson (1995), Thrusfield (1995), Kleinbaum et al. (1998), Rothman and Greenland (1998), Brown and Prescott (1999) and Twisk (2003).

[11] Unfortunately, the term *study variable* is sometimes used as synonym for the *response variable*.

[12] The term *risk* is used in epidemiological texts with very different meanings (Kunkel et al., 1998); in the remainder of this thesis, I use it synonymously with *cumulative incidence*.

been recommended for calculating the incidence of metritis, ketosis, ovarian disorders, left displaced abomasum, lameness and clinical mastitis. In current analyses, (true) incidence rates have been recommended for the latter diseases (Kelton et al., 1998). Incidence odds are the ratio of the proportion getting the disease to the proportion not getting the disease, or risk/(1–risk). Because of the statistical properties of odds, they are often used as approximations of risks, for example in logistic regression. The approximation works fine as long as the risk is relatively low (at values $\leq 10\%$, the denominator in the calculation approaches 1).

The *incidence rate* of disease occurrence is the instantaneous potential for change in disease status (i. e. , the occurrence of new cases) per unit of time t. Compared with the risk, rates are better response variables when the study population is open (cows enter or die during the study period) or when more than only the first case is of interest. A disadvantage of using rates is that they are conditional on the (daily) disease risk remaining constant throughout the study period (e. g., one cow observed for 200 days 'counts' as much as two cows observed for 100 days). If this is not the case, the risk period has to be broken up into periods of shorter length during which the disease risk is constant.

The *hazard* is — like odds and risks — a conditional probability; the probability of a disease-free individual's developing a disease at the next point in time conditional on that individual's not dying from any other disease up to that point. It can be used to approximate risk when the study population is open — observations of subjects leaving the study population before the end of the at-risk period (e. g., cows that were culled during lactation) are *right-censored*. Using a proportional hazard model to model the response variable makes it necessary to assume that any subject that *was not* observed for the entire risk period would have had the same risk of being treated as a cow that *was* observed for the entire risk period (to avoid bias from *informative censoring*). This assumption is probably not fulfilled when using veterinary treatment data from the database because cows are often culled to avoid treating them. Measuring the hazard of first insemination and conception has been recommended for the calculation of cows' fertility (Harman et al., 1996a).

Causal inferences from epidemiological studies are often based on a *counterfactual argument*; the effect of a cause is studied as if the same group of animals in the same context (i. e., at the same time, in the same place) was exposed and non-exposed. An important feature of counterfactual arguments is that they involve two distinct conditions — e. g., an exposed group and an unexposed comparison group. To ask for *the* effect of exposure is meaningless without reference to some other conditions.

The *target population* in epidemiological research is the immediate population to which the results from the research will be extrapolated. When the research does not involve all animals in the source population (*census*), a sample is studied — the *study population*[13]. The study population should consist of subjects (e. g., animals or farms) which are representative of the target population with regard to the studied effects (e. g., in a study on the effects of cows' breed on milk yield, cows in the study population should show a 'typical' breed effect) — they need not be representative of the target population regarding characteristics that are unrelated to the studied effects. *Generalizability* denotes the breadth of applicability of the conclusion from epidemiological research — basically, the breadth of the target population.

The *validity* of a study is usually separated into two components: the validity of the inferences drawn as they pertain to the animals of the source population (*internal validity*), and the validity of the inferences as they pertain to animals outside that population (*external population*). *Bias* has occurred when the result of an epidemiological study using a study population is not valid in the target population. One reason for bias is *measurement error* (for example, healthy cows might be registered as diseased or exposed cows as unexposed). Measurement error generally can distort results of a study in both ways — estimated effects can be an underestimation or an overestimation of true effects. This bias is particularly problematic when subjects in different groups have a different risk of being misclassified (*differential misclassification*). *Selection bias* occurs when the relation between exposure and disease is different for subjects participating in the study and individuals that would theoretically have been eligible for study. It is caused by the non-representative selection of animals from the target population. *Confounding*, finally, is the third way of causing bias. It can be caused by effects of the context in which the study took place. This is the only bias that can be avoided or at least reduced with the help of stratified analysis or statistical modelling. A variable is a *confounder* when a) it is a risk factor in unexposed individuals,

[13]Even when using the whole target population (e. g., cows from all cold loose-housing farms in Finland during the study period), the observation is still treated as a sample because the target population also includes cows at later times.

b) it is correlated with the study variable and c) in a clinical trial, it would have been controlled in the setting of the trial. A variable is not a confounder when it is on the causal pathway between study variable and response — these variables are *intermediate variables*, and controlling them in the statistical analysis causes bias (Greenland, 1989).

1.4.2 Definitions and concepts in statistics

Statistical models can be used for many different purposes, one of them to describe quantitatively or qualitatively the relationship between the study variable ($X_1, X_2, \ldots X_k$), and the response variable (Y), while controlling for the effects of other variables ($C_1, C_2, \ldots C_n$) believed to have an important relationship with the dependent variable. The choice of the model used for the statistical analysis depends on the the way the response variable is measured, the purpose of the model and how the available information can be utilized most efficiently: Logistic regression often is used for binary and binomial distributed variables, Poisson analysis for counts, survival analysis for time-to-event data and some kind of linear regression for continuous variables. Logistic regression, Poisson analysis and linear regression (and other models, but not survival analysis) can be summarized under the framework of generalized linear models.

One assumption in using regression models in their 'native' form is that the observations are independent of each other and identically distributed[14]. A *correlation* between observations violates this assumption and can render results from epidemiological studies invalid (e. g., Schukken et al., 2003). To correct for correlation between individuals in the study population (e. g., cows in a herd), *covariance pattern models* have been developed. A correlation can alternatively be expressed as a (large) collection of unknown (*latent*) variables — the farmer's unmeasured attitudes and preferences, the unknown number of infectious cows on the farm, the unidentified effect of a particular bedding to name but a few. To correct for these latent variables, *random effects models* and *random coefficient models* have been developed. Covariance pattern models, random effects models and random coefficient models belong to the family of *mixed models*. Results from different mixed models have a slightly different interpretation — results from logistic regression, e. g., using a co-

[14] To be more exact, it is the *residuals* that are assumed to be 'iid'.

variance pattern model to correct for a correlation, are different from results using a random effect model (Twisk, 2003).

The sequence of entering or dropping different variables into or from the model — *model selection* — can influence the estimated effect of study variable the response. For variables with unknown effects in explanatory data analysis, different model building strategies have been developed and recommended. Two key criteria for selecting an optimal strategy are the purpose of the model and the quantity and quality of available data (Greenland, 1989).

Model diagnostics are descriptive and statistical methods for checking the adequacy of the model. One such diagnostic is the analysis for *influential values* or *bad leverage points* — observations that change the estimates for a parameter drastically if they are dropped from the model (Rousseeuw and van Zomeren, 1990). Checking for influential values is necessary because results from a model with influential values might not be externally valid. For the detection of influential values in regression models in their 'native' form, model diagnostics, such as calculation of leverage, are incorporated into some statistical packages (e. g., STATA or SAS). For detection of influential values in mixed models, the leverage of single observations (e. g., cows) does not provide much information, especially when the study variable is measured on a higher level (e. g., herds). A more informal way to detect influential values is to leave out every observation one at a time (e. g., every cow or farm) and re-run the analysis.

The *significance* of results from statistical models can be divided into *statistical* and *practical* significance. The *statistical significance of a result* is the probability of seeing as big or even a bigger difference as we did if the null hypothesis were true. It is a function of many factors, including magnitude of the effect, sample size, reliability of the effect and reliability of the measurement instrument. Because statistical significance is affected by sample size, it is a very 'dangerous' tool for inference — independent of the magnitude of the effect, almost every large study will show statistically significant differences, but no study will show any statistical significant difference if the sample size is too small. *Practical significance*, on the other hand, relates more to the magnitude of the effect and is unaffected by sample size. It is dependent on the subjective interpretation of the individual, it is a combination of the probability of the effect and its consequences[15]. To

[15] In risk analysis, this is a definition for the *risk*.

clarify the difference between statistical and practical significance, imagine a statistically significant increased risk of ketosis of 20%. For a farmer with 15 cows who sees only one case of ketosis every 10 years, the 20% increase is certainly not (practically) significant. However, for a nation like Finland with, say, 500000 cows, the same 20% increase in risk might very well be (practically) significant (at least for welfare and breeding organizations). Practical significance is probably more often expressed as a *risk difference* (e. g., how many more cows on the farm with 15 cows will be diseased after a change in loose-housing systems?), while statistical significance is often expressed as a *risk ratio* (e. g., is the cows' risk of contracting mastitis significantly higher when kept in a CLH?).

Results from observational studies cannot be used to prove causation. They are merely indicative of association.

II

Aims of the study

The primary aim of this work was to estimate the effect of the type of loose-housing on cows' health, production and reproduction and to estimate the effect of breed on cows' health. To obtain internally as well as externally valid estimates, I had to find valid ways of estimating disease incidence, milk yield and fertility in the target population and then valid ways of comparing these estimates between cows in the two loose-housing systems or between cows of two breeds. I tested the following (two-sided) hypotheses:

$H_0 1_1$: No significant increase or decrease is present in the incidence of reproductive and metabolic disorders and diseases of the mammary gland in cows due to calving in a CLH compared with calving in a WLH during a period in which cows were most likely confined.

$H_0 1_2$: No significant difference is present in the incidence of ovarian disorders and diseases of the mammary gland in cows due to being housed in a CLH compared with being housed in a WLH during some parts of the cows' lactation, during a period in which cows were most likely confined.

$H_0 2$: No systematic difference is present in the amount of milk obtained from cows kept in a CLH as compared with cows kept in a WLH at any time during their lactation.

$H_0 3_1$: No systematic difference is present in the time from calving to first service in cows calving and being inseminated in a CLH compared with cows calving and being inseminated in a WLH.

$H_0 3_2$: No systematic difference is present in the first-service-pregnancy risk in cows calving and being inseminated in a CLH compared with their counterparts in a WLH.

$H_0 3_3$: No systematic difference is present in the repeated-service-conception hazard of cows calving and being inseminated in a CLH but failing to conceive at first service compared with their counterparts in a WLH.

H_04_1 : No significant difference is present in the incidence risk of reproductive and metabolic disorders and diseases of the mammary gland in early lactation between Finnish Ayrshire cows and Finnish Black and White cows.

H_04_2 : No significant difference is present in the incidence rate of diseases of the mammary gland in late lactation between Finnish Ayrshire cows and Finnish Black and White cows.

Hypotheses H_01_1 and H_01_2 were tested in Study I (Comparison of the disease incidences of dairy cows kept in cold and warm loose-housing systems); hypothesis H_02 was tested in Study II (Comparison of milk production of dairy cows kept in cold and warm loose-housing systems); hypotheses H_03_1, H_03_2 and H_03_3 were tested in Study III (Comparison of the breeding performance of cows in cold and warm loose-housing systems in Finland); and hypotheses H_04_1 and H_04_2 were tested in Study IV (Comparison of the disease incidences of Finnish Ayrshire and Finnish Black and White dairy cows).

III

Materials and methods

3.1 Target population, study population and study periods

The target population of the study comprised Ayrshire and Black and White dairy cows in Finland and in areas where cows are kept under similar conditions (Table 3.1). The target population was further defined by housing type (only loose-housed cows) (I–III) and calving period (only winter calving) (I and III).

The study populations were cows from farms registered at the Finnish data processing centre (≈ 77% of all Finnish dairy farms were registered; Saloniemi and Kulkas, 2001). Farms were included in the study population only when information on the type of housing (mainly loose-housing and tie stalls) was available (≈ 40% of the farms in the database) and farmers had filled in a postal questionnaire (I–III). Only cows that had calved during the study period, 1996/1997 (I–III) or 2000 (IV), were included. Furthermore, cows in Studies I and III must have calved during wintertime, which was necessary because many cows are on pasture during the summer months and not exposed to the loose-housing.

Table 3.1: Typical production conditions for Finnish dairy production.

Feeding	Off-pasture time mainly grass silage supplemented with cereals (barley and rye or commercial concentrates; maize not used as feed)
Breed	Finnish Ayrshire and Finnish Black and White
Climate	Boreal, semicontinental
Herd size	Mean 15.5 cows per farm (1998)
Organization	88% of farms were privately owned[1]
Producer price	0.40 €/litre (1999)

[1] Another 11% were also privately owned but registered as a company; only 1% were state-owned.

3.2 Response variables

Response variables were incidences of veterinarian treatments of udder and ovarian disorders, parturient paresis, ketosis and metritis (I and IV) as well as test-day milk yield (II) and days-to-first-service, first-service-conception risk and repeated-service-conception hazard (III) (for definitions of the diseases, see Table 3.2 on the next page). All necessary information on these variables was collected from the Finnish health recording scheme or the Finnish milk and fertility recording scheme. In these databases, misclassification of disease variables (especially underreporting) was expected. Nevertheless, the misclassification should not have not caused serious bias in calculating the odds ratio because the data were assumed to have high specificity (Rothman and Greenland, 1998) (I and IV). Misclassification of parturition and insemination dates in the Finnish milk and fertility recording scheme was not expected, although a few farmers ($\approx$ 5% in WLH and 10% in CLH) use their own bulls for some matings (mainly heifers), and these are not recorded in the database (III). Misclassification of the response variable was reduced by excluding observations with illogical disease data (I and IV), culling data (I–IV), insemination data (III) or yield data (II).

An incidence risk was calculated for metritis, ketosis, parturient paresis, ovarian disorders and early mastitis ($\leq$ 14 days in milk (DIM)). An incidence rate was calculated for late mastitis (15 to 305 DIM) (I and IV). Definitions for lactations-at-risk or days-at-risk have been chosen to minimize effects of culling and unequal risks throughout lactations. In the calculation of incidence in cold and warm loose-housing systems (I), additional consideration was given to short observation periods (only winter months were studied) and to different definitions of exposure (*calving* or *being* in a CLH (see below)): a disease-specific period-at-risk was defined as the period from calving until the DIM at which 75% of cases had occurred. In the calculation of the incidence in Finnish Ayrshire and Finnish Black and White cow (IV), external data (Østerås et al., 2002) were used to calculate the point in lactation at which the fewest observations were deleted and simultaneously the fewest lactations were classified as healthy, although the cow contracted the disease afterwards (Figure 3.1 on page 32, cow 2). In both studies, observations with follow-up periods that were shorter than the disease-specific period-at-risk were deleted if the cow did not contract the disease during the follow-up period (Figure 3.1 on page 32, cow 3). Observations with follow-up periods that concluded at the end of the study period were deleted independent of

Table 3.2: Definition of diseases, timing of first treatment, incidence risk and the period-at-risk used for the comparison of the cows' health between Finnish Ayrshire and Finnish Black and White cows (208,098 Ayrshire and 72,105 Black and White cows; Study IV)[1].

Disease	Veterinarian-treated cases of	Days in milk at first treatment (Min; Median; Max)	LIR (%)[2]	Period-at-risk (days in milk)
Mastitis	clinical, subclinical and chronic mastitis	0; 28; 305	14.1	0 to 14 and 15 to 305
Parturient paresis	clinical parturient paresis, downer cow	-1; 1; 305	4.3	-1 to 3
Ketosis	primary and secondary ketosis	0; 26; 301	1.5	0 to 41
Ovarian disorders	ovarian cysts, delayed ovulation, follicle atresia	0; 94; 305	9.7	31 to 116
Metritis	acute and chronic metritis, pyometra, vaginitis, disturbed involution	0; 17; 305	1.4	0 to 19

[1] Definitions and periods-at-risk were slightly different in Study I; see article.
[2] LIR=number of first cases/number of calvings.

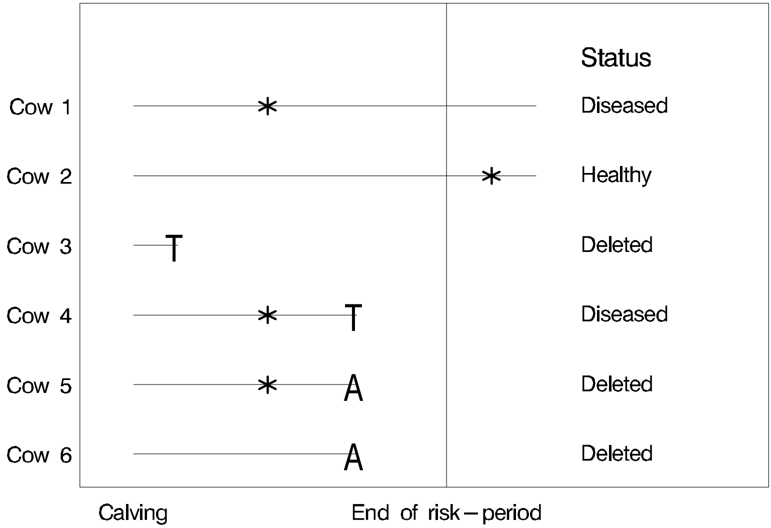

Figure 3.1: Calculation of incidence risks. '∗' denotes a case; 'T' denotes a cull; 'A' denotes the end of the study period (I and IV).

the disease status (Figure 3.1, cows 5 and 6).

In the studies on the effect of the type of loose-housing on the incidence risk of ovarian disorders and the incidence rate of late mastitis (I), the exposure might not have been *calving* in a CLH but *being* in a CLH. Therefore, the effect of type of loose-housing on the incidence risk of ovarian disorders was tested with a second definition of the period-at-risk. For the calculation of the incidence risk of ovarian disorders under H_01_2, the period-at-risk started at 60 DIM. Observations from cows with a case occurring between calving and 60 DIM were deleted. The effect of type of loose-housing on cows' incidence rate of late mastitis was calculated by dividing the sum of all cases of late mastitis that the cow contracted during the indoor period by the sum of all days the cows spent indoors.

Crude median incidences of the diseases on farms for the two systems (CLH and WLH) and for the non-responders to the questionnaire in Study I (Figures 3.2 on the next page [Incidence risks] and 3.3 on page 34 [Incidence rates]) showed very low incidence risks and rates — for most diseases,

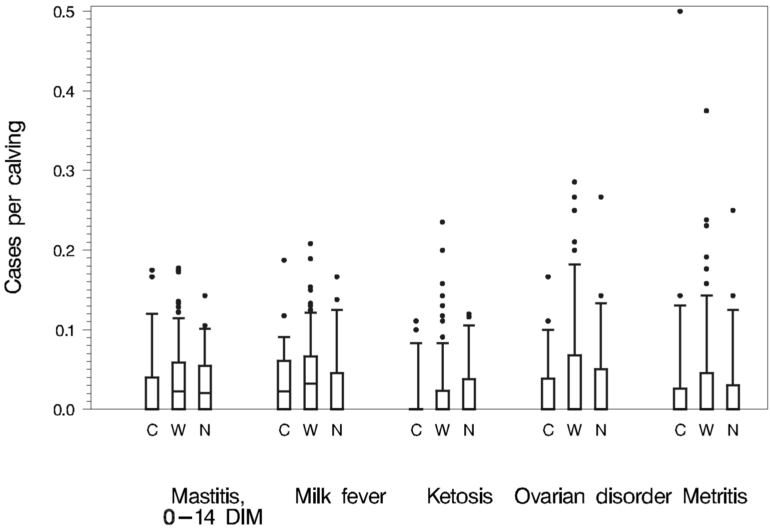

Figure 3.2: Box-and-Whisker plots for cows' incidence risk of early mastitis, parturient paresis, ketosis, ovarian disorders and metritis for CLH (C), WLH (W) and non-responders to the questionnaire (N) (calculated at farm-level) (Study I). The median incidence risk (indicated by a vertical bar in the box) shows that more than 50% of the farms had not had any case of ketosis, ovarian disorders or metritis registered during the study period.

more than 50% of the farms had not had any case registered during the study period. Moreover, some farms had a very high incidence, which is mostly due those farms having very few calvings during the study periods. Finally, cows on farms from which the questionnaire was not returned (non-responders) did not fare (much) differently (in terms of location and spread of data) than cows on farms from which the questionnaire was returned (CLH and WLH). In the study on the effect of breed on disease incidence, crude median incidences showed that disease risk in loose-housing and tie-stalls was zero for most of the diseases, and that cows on farms where no information on housing type was available did not fare much differently (Figures 3.4 on page 35 [Incidence risks] and 3.5 on page 36 [Incidence rates]).

The response variable in Study II was cows' test-day milk yield. Milk

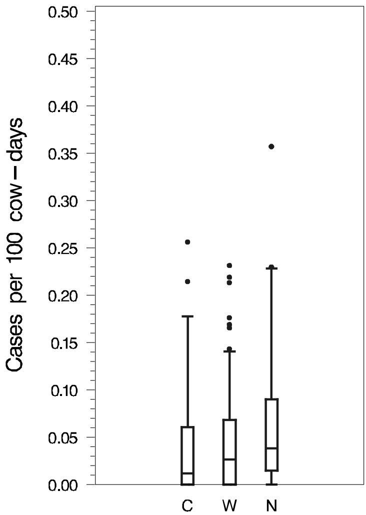

Figure 3.3: Box-and-Whisker plots for cows' incidence rate of late mastitis for CLH (C), WLH (W) and non-responders to the questionnaire (N) (calculated at farm-level) (Study I). Both median incidence rate of late mastitis and the spread of the data was slightly higher in non-responders, indicating potential bias.

was collected at approximately 30-day intervals from every cow in production in the study population. Cows' test-day milk yield is a combination of cows' morning and evening milk yield at two successive milkings obtained from all cows in production between 5 and 305 DIM. It is the *raw* observed milk yield (not corrected for milk constituents) because for milk constituents *fat* and *protein*, only 305-day cumulative summaries were available. Test-day milk yields on farms of the two housing types and of the non-responders to the questionnaire showed typical lactation curves. Several of the test-day values are extremely high and are probably measurement or recording errors; the spread of the data seems equal, both within the housing systems over time and between the housing systems at specified time intervals (Figure 3.6 on page 37).

The response variable in testing $H_0 3_1$ was days from 30 days after calving to first service (the first 30 days after calving were arbitrarily excluded

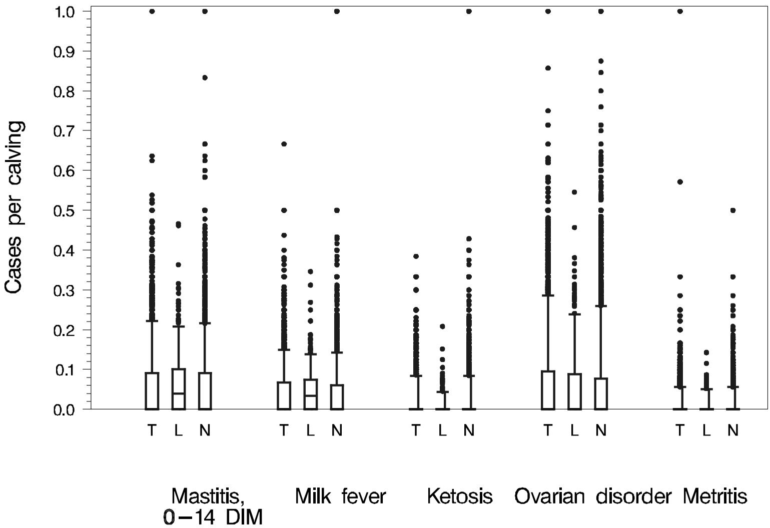

Figure 3.4: Box-and-Whisker plots for incidence risk of early mastitis, parturient paresis, ketosis, ovarian disorders and metritis for cows in tie-stalls (T), loose-housing systems (L) and farms where housing type was unknown (N) (calculated at farm-level) (Study IV).

because cows inseminated during that time are for biological reasons almost certainly not at risk of conception)[1]. In calculating the response, an event (first service) was counted only if it took place in the same winter period in which calving had occurred; all other observations were right-censored (for a detailed description of the censoring, see Study III). Crude estimates for the time from calving to first service showed similar survival functions, and the median period from calving to first service was about 72 days in both housing types (Figure 3.7 on page 38). These estimates are lower than the national average, which might be due to observations of cows calving towards the end of the winter period were more likely being censored if cows had long periods to first service than if they had short periods.

[1]In human epidemiology, this period is known as 'immortal person-time' (Rothman and Greenland, 1998) — here, it might be called 'immortal animal-time'. It is not synonymous with the 'voluntary waiting period', which is based on management decisions and very different from farm to farm.

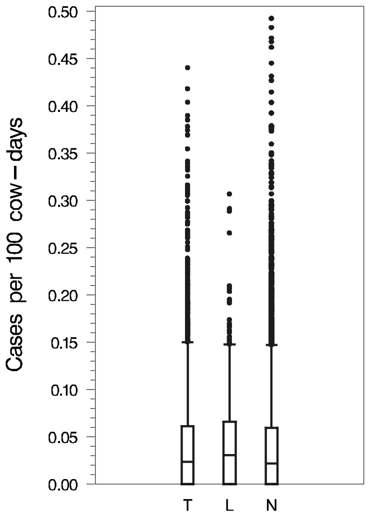

Figure 3.5: Box-and-Whisker plots for incidence rate of late mastitis for cows in tie-stalls (T), loose-housing systems (L) and farms where housing type was unknown (N) (calculated at farm-level) (Study IV).

The response variable in testing $H_0 3_2$ was the first-service-conception risk. In calculating the response, an observation was retained in the data set only if the cow calved and was inseminated for the first time during the same winter period, and an observation was deleted from the data set if the cow was inseminated less than 30 days after calving. Crude estimates for the first-service-conception risk based on 2230 cows showed that $\approx$ 56% of the cows conceived at first service (Table 3.3 on page 39). This probability of conception is slightly higher than the national average for winter-calving cows, which might be due to better fertility of loose-housed cows (Valde et al., 1997).

The response variable in testing $H_0 3_3$ was the period from first unsuccessful service to conception. In calculating the repeated-service-conception hazard, inseminations that were less than 5 days apart were counted as one (repeated inseminations, $\approx$ 5% in both loose-housing systems, are normally only done when the farmer has misjudged the timing of the ovulation; they are generally unrelated to the fertility of the cow). An observation was in-

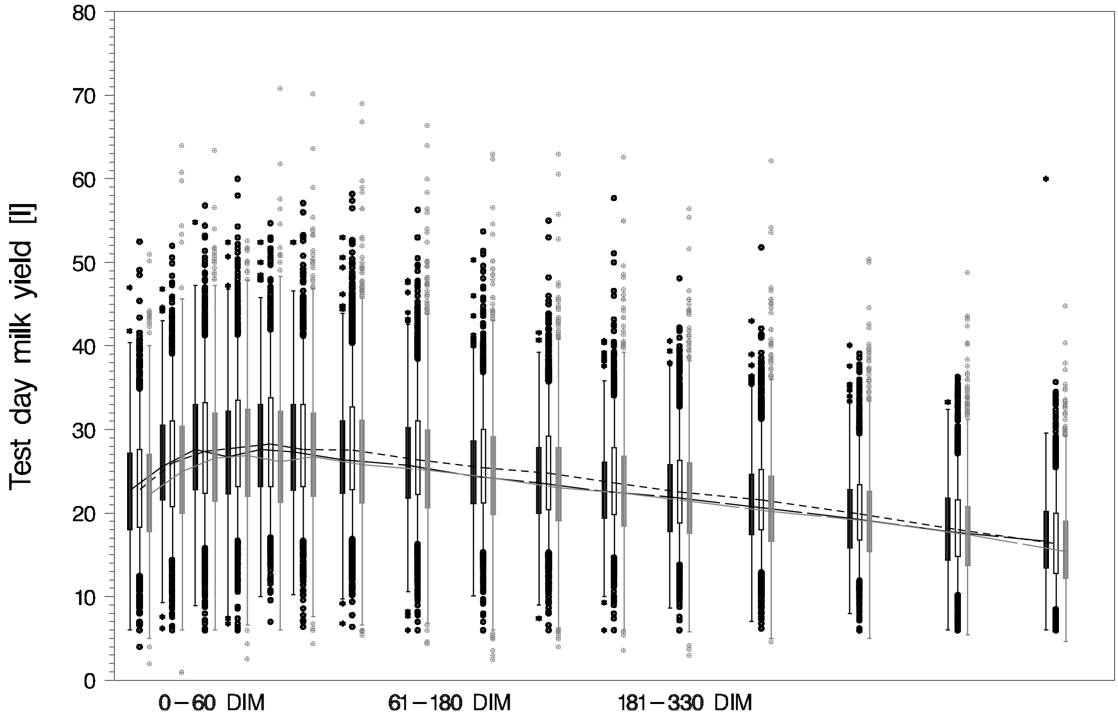

Figure 3.6: Box-and-Whisker plots for cows' milk yield for CLH (closed, black boxes), WLH (white boxes) and non-responders to the questionnaire (gray boxes) (calculated at cow-level). The medians were connected, resulting in a typical lactation curve. Neither median nor spread of the data was different between CLH, WLH and non-responders. Outlying low values could indicate a diseased cow; outlying high values are more likely indicative of a measurement error (Study II).

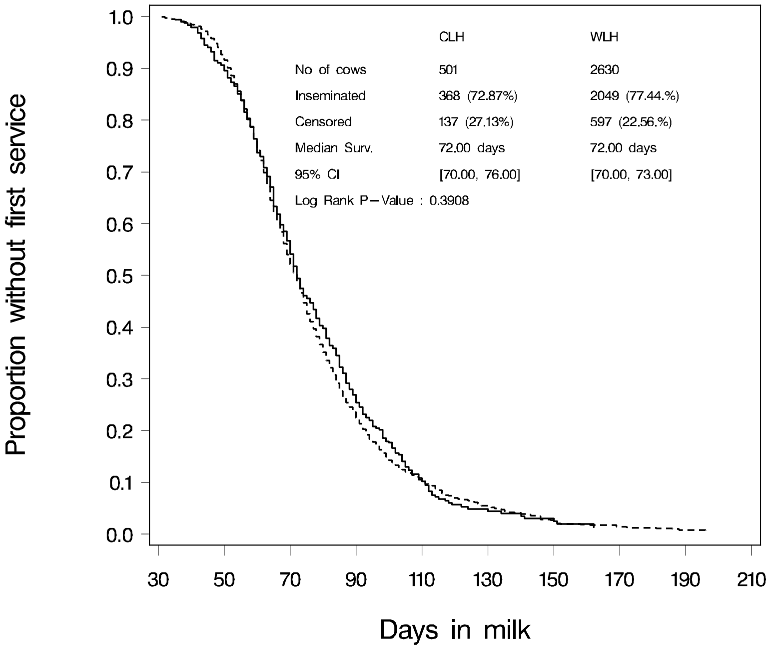

Figure 3.7: Kaplan Meyer graph of the time from calving to first insemination in cold loose-housing systems (CLH; solid line) and warm loose-housing systems (WLH; broken line). The proportion of cows not serviced is almost identical at each point in time between the two housing systems, which is reflected in the non-significant log rank *P*-value.

Table 3.3: Observed risk of conception in cold and warm loose-housing systems in Finland (208 farms, 1996 and 1997).

Insemination number	Type of loose-housing	No. of inseminations	% conceived
1	cold	339	49
	warm	1891	57
2	cold	123	54
	warm	548	53
3	cold	37	35
	warm	141	55
4	cold	16	44
	warm	32	41
5	cold	3	33
	warm	9	33
6	cold	1	0
	warm	2	0
7	cold	1	0
	warm	1	0

cluded in the data set when the cow failed to conceive at first service and had at least one more insemination during the same winter period in which she calved. In calculating the response, an event (the successful insemination) was counted only when it took place in the same winter period in which calving had occurred; all other observations were right-censored (for a detailed description of the censoring, see Study III). Descriptive statistics of the repeated-service-conception hazard showed a decreasing fertility with increasing insemination number (Table 3.3), which is — at least partly — due to the more fertile and healthy cows conceiving already at first service, leaving only less fertile cows at risk of further inseminations (Weinberg and Wilcox, 1998).

3.3 *Study variables*

Two variables were studied: the type of loose-housing (I–III) and the breed of the cow (IV). The housing system was classified according to answers to the

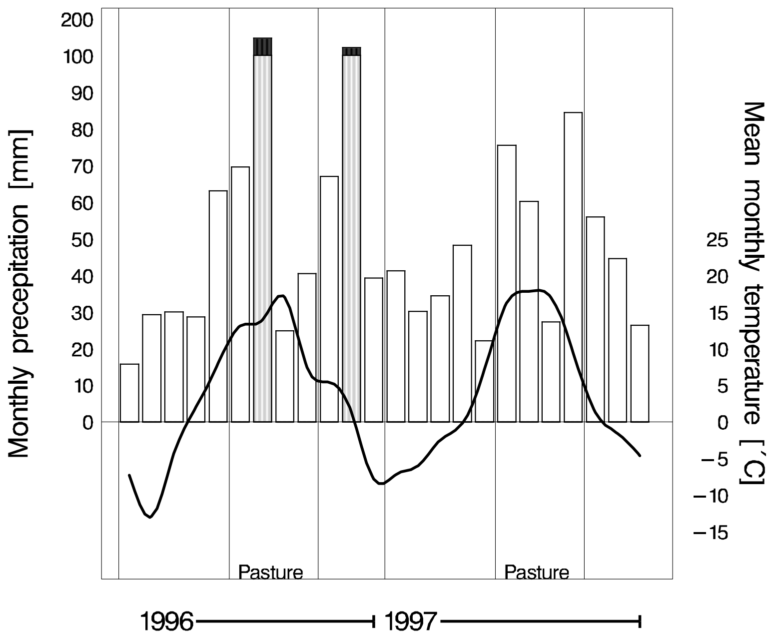

Figure 3.8: Macro-climatic conditions in the study periods of Studies I–III in an area in central Finland where some of the CLHs were located — Kuorevesi [61.5°N,24.5°E], 143 m above sea level. In the estimation of the effect of type of loose-housing on cows' health and fertility (Study I and III), pasture time was excluded.*Source:* Finnish Meteorological Institute, Yearbooks 1996 and 1997.

questionnaire. A farm was classified as a loose-house if the cows were not tied up. Loose-houses were *cold* when the climatic conditions inside the barn were assumed to be similar to outside conditions throughout the year (Tuure, 1995; Figure 3.8). Loose-houses were *warm* when the construction of the barn ensured a relatively constant inside temperature throughout the year. Barns with roofs made of transparent material, the so-called 'greenhouses', were included as CLHs, although they do not exactly comply with the definition ($n \approx 5$)[2].

[2]Environment and management of a *real* CLH and a greenhouse are very similar, but in the latter, the temperature might be warmer and the air more humid than outside conditions. Their number

In most models of Studies I and II, the exposure was defined as *calving* in a CLH or in a WLH. In the model for late mastitis in Study I, it was defined as *being confined* in a CLH or WLH; in the second model for ovarian disorders in Study I, it was defined as *being confined during the period from 30-60 days after calving* in a CLH or a WLH. In Study III, the exposure was defined as *calving and being confined for the first 30 days after calving* in a CLH or WLH ($H_0 3_1$), *calving and being inseminated for the first time* in a CLH or WLH ($H_0 3_2$) and *calving and being inseminated at least twice* in a CLH or WLH ($H_0 3_3$).

The breed of the cow was classified according to information provided by the Finnish Data Processing Centre, where a cow's breed is defined by its sire's breed; cross-bred cows ($\approx 1 - 6\%$; Hellman 2002, personal communication; Rautala 2002, personal communication) are wrongly classified.

3.4 Confounders

A self-administered questionnaire (I–III), the Finnish milk recording scheme (I–IV) and a data base from the Finnish Meteorological Institute (IV) were used to collect data on factors that have been reported to be related to the response variables. The questionnaire included 104 questions on the management and equipment of loose-housing systems (Appendix 1 and 2). Results from the questionnaire were categorized and, if necessary, a dummy variable for missing values was created. Several differences emerged between CLH and WLH in management and equipment, many of these being adaptations to temperatures below freezing (Table 3.4 on the following page).

Potential confounders that were included in all full models in the statistical analysis (I–IV) were cow's parity and calving period. The calving period in Study IV was defined by the start and end dates for the growing season in the area where the farm was located[3]. Cow's breed was added as a confounder to all models testing the effect of type of loose-housing (I–III). Depending on the response variable, several additional factors regarding farm management and equipment (I), veterinary treatments for seven disorders (III) and days from the previous insemination (III) were added. Interactions

in the study population depends on the exact definition of a greenhouse.

[3]The growing season starts after a period of five consecutive days with daily mean temperatures $> 5°C$ and is corrected for the area which is snow covered and for low degree-days five days after the beginning of the growing season (Finnish Meteorological Institute, 2003).

Table 3.4: Examples of differences between CLH and WLH.

Variable	CLH	WLH
Year of building (mean)	1994	1989
No. of feeding places (per cow, mean)	1	0.6
Cleanliness of the cow (mean score from 1 (dirty) to 6 (clean))	4.7	4.8
Cubicle size (cm, median)	235 × 120	220 × 120
Use of pasture (%)	22	31
Use of litter (%)	100	90
Type of litter (%, if used)		
Straw	90	8
Cutter	6	60
Peat	55	20
Sawdust	8.5	18
Use of a separated box for diseased cows (%)	62	90
Use of milking parlour (%)	67	99
Teat dipping (%)	55	24
Farmer reports cows laying in the alley (%)	22	59
Cows are dehorned (%)	81	100
Organic production (%)	13	6
Fly-control in the barn (%)	81	57
Scoring for working conditions in winter (from 1 (bad) to 6 (good), percentage of farms scoring under 4)		
Heat	17	7
Humidity	4	26
Light	9	1
Air quality	2	9
Feeding		
Use of automated feeding (%)	67	90
Lead-feeding (%)	89	96
Ad libitum silage feeding (%)	81	70
Silage pre-wilted (%)	93	66
Hay for cows (%)	63	70
Hay for dry cows (%)	64	68
Commercial concentrates (%)	52	68

of the study variable with any of the variables breed, parity and calving season were tested.

All variables that were included in the final multilevel models studying the effect of type of loose-housing (I–III) — with the possible exception of breed of the cow — could have acted as intermediate variables. For example, there might be a (never reported) causal correlation between parity of the cow and type of loose-housing. It is therefore important to include results of the unconditional regression analysis in the interpretation of the results.

3.5 *Statistical analysis*

A large battery of statistical methods have been used in the analyses. Logistic regression was used to test incidence risks (I and IV) and the first-service-conception risk (III). In addition, Poisson analysis was used to test incidence rates (I and IV), linear regression to compare cows' milk yield (II) and survival analysis to compare the days to first insemination (III) as well as the cows' repeated-service-conception hazard (III). Statistical software packages used for analysis were MLWIN (I), SAS (I–IV) and STATA (III). If not mentioned otherwise, to assess statistical significance, an error margin of 5% for type I error was used.

3.5.1 Correlations

The most important correlations were between cows of the same herd (I–IV), between lactations of the same cow (I–IV) or between test-day milk yields of the same cow in the same lactation (II). Additional correlations might also exist between genetically related cows, between farms in adjacent geographical areas or between cows that were treated by the same veterinarian.

To correct for the correlation between cows of the same herd, a random effect model was used for all analyses except Study IV and Study III for the repeated-service-conception hazard. The random effects in these models were assumed to follow a normal (I–IV) or gamma (III) distribution. In Study III, the correlation between cows of the same herd was ignored in the calculation of the repeated-service-conception hazard. To correct for the correlation in Study IV, a covariance pattern model was used, assuming a constant correlation between observations. The correlation between two lactations of the same cow was either ignored (I and III) or one of two lactations was randomly deleted (using computer-generated random numbers; II and IV).

To correct for the correlation between test-day results, a random coefficient model was used in Study II. Other correlations were ignored.

3.5.2 Model building strategies

In Study I, the model building strategy was to first identify relevant confounding variables ($P < 0.1$), build the best model possible without the study variable and then evaluate whether the study variable was related to the response variable while adjusting for the confounding variables. In Studies II–IV, the strategy was to reduce full models (including all potential confounders and several interaction terms) in a manual stepwise backwards procedure, deleting first the non-significant interaction terms and then the non-significant main effects that were not included in the remaining interaction terms. In Study III, the effect of any potential confounder on the shape of the lactation curve was tested *en block* — any variable that did not significantly affect the shape and the intercept of the curve was deleted.

3.5.3 Model diagnostics

To highlight single farms with a high influence on the estimated parameters, final models were re-run with each farm deleted one by one (I and III). To highlight missing variables and outlying values, different residual plots were generated (I–IV). To evaluate bias from the inclusion of farms immediately from the commissioning date of a new barn, it was tested whether the fit of the models could be improved by splitting the group of cows that were kept in a CLH into a subgroup of cows that calved within one year after the commissioning date and a second subgroup of those that calved after this period (II and III). To evaluate bias from farms using their own bull for some inseminations, all models in Study III were tested excluding those farms. To evaluate bias from herds with extremely high culling frequencies ($> 50\%$), models in Study IV were run with those farms excluded. Finally, to avoid bias from cows that were most probably not at risk of treatment for ovarian disorders (those that were neither inseminated nor treated for ovarian disorders during the risk period), the models in Study IV examining the effect of cow breed on the risk of being treated for ovarian disorders were run without these cows.

3.5.4 Presentation of results

Because I was interested in the risks of conception (III) and the risks of being treated for any of the diseases but late mastitis, results from the logistic regressions (log-odds) in (II) and (IV) were re-calculated and expressed as risks for all possible combinations of factors in the final models. For the re-calculation, the formula: $\hat{y} = \frac{exp(\mathbf{X}\hat{b})}{1+exp(\mathbf{X}\hat{b})}$ was used[4].

To estimate the number of additional cases a farmer on a typical farm would see if she would change to a different breed, the estimated risks and rates for all possible combinations of factors in the final models (IV) were multiplied by the observed number of animals in a median-sized farm and then summed-up. For example, $\approx$ 50% of the farms had one parity 1 cow and two parity 5 cows calving during the pre-growing period. Given an estimated risk of 0.07 and 0.075 in Black and White cows for early mastitis in parity 1 and parity 5 cows, respectively, the total risk of early mastitis on the median farm would have been $0.07 + 2 * 0.075 = 0.22$, or about 20%.

[4]For the estimation of the first-service-conception risk, this assumes a farm with a mean farm effect.

IV
Results

4.1 *Effects of type of loose-housing on health, production and fertility*

4.1.1 COMPARISON OF DISEASE INCIDENCE

In Study I, the disease incidences of cows kept in approximately 40 cold and 120 warm loose-housing systems were compared. The study population comprised cows that calved during the indoor-periods in 1996 and 1997. In the study, a statistically significant difference could not be demonstrated for most of the diseases. The only statistically significant difference was in the incidence of metritis; compared with Friesians in WLHs, Friesians in CLHs had less metritis (Figure 4.1 on the next page).

Based on the assumption that a 20% increased or decreased risk of all of the diseases would result in a 'practically significant difference', findings from Study I can be used to rule out (with 95% confidence) a negative association between calving in a CLH and the incidence of parturient paresis and a positive association between calving in a CLH and the incidence of ovarian disorders. For the other diseases, neither positive nor negative, nor no associations could be ruled out. The most likely values nevertheless indicate that cows in CLH were at lower odds for contracting late mastitis and metritis (Friesian breed) and at higher odds for contracting parturient paresis and metritis (Ayrshire breed).

4.1.2 COMPARISON OF MILK YIELD

In Study II, the milk yield of cows kept in the same cold and warm loose-housing systems as in Study I was compared, but in contrast to that study, the study population comprised cows calving throughout the two-year study period. In the study, a statistically significant difference between cows in CLH and WLH could not be demonstrated ($P = 0.11$). The most likely values indicated that cows in the CLH produced up to one litre less milk per test-day (Figure 4.2 on page 49). Based on the assumption that a 10% increased or

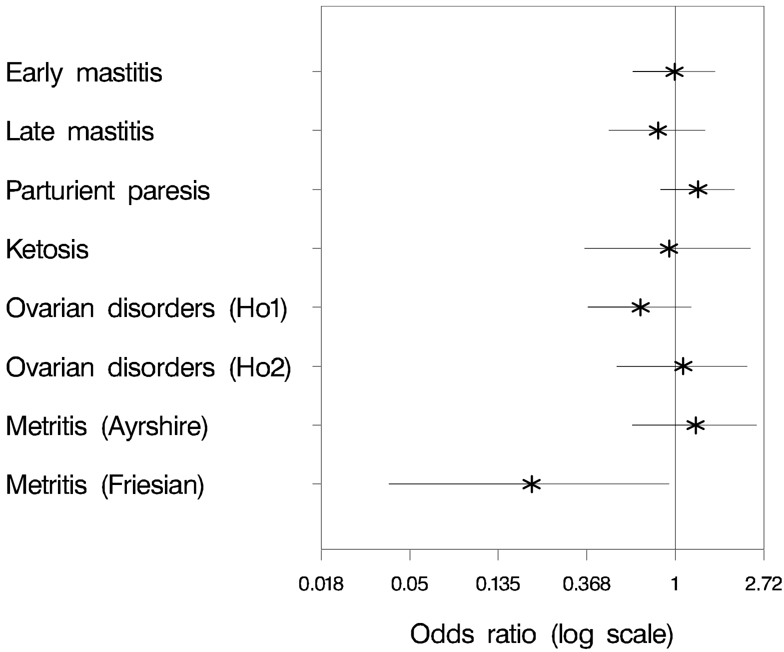

Figure 4.1: Effects of CLH versus WLH (reference) on the incidences of mastitis, parturient paresis, ketosis, ovarian disorders and metritis in dairy cattle (Finland, 1996 and 1997) (I).

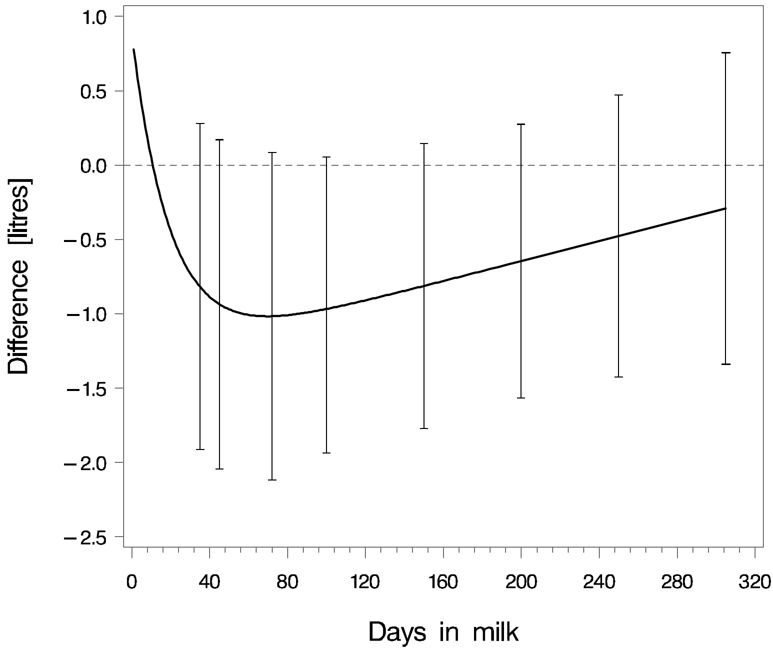

Figure 4.2: Predicted mean difference in the lactation curves for cows kept in cold or warm (reference) loose-housing systems (CLH and WLH, respectively) in Finland in 1996 and 1997. Point estimates and 95% confidence intervals were calculated for the differences in litres at 35, 45 (predicted peak milk yield in CLH and WLH), 72 (largest predicted difference), 100, 150, 200, 250 and 305 days in milk.

Table 4.1: Accelerated failure-time model for the time from calving to first service in cold and warm loose-housing systems (adjusted for parity and diseases) (Finland, 1996 and 1997; Study III).

Type of loose-housing	Acceleration factor	*P*-value	95% CI
Warm loose-housing	1.02	0.64	0.88 to 1.08
Cold loose-housing	1	-	-

decreased (305-day) milk yield would make a significant difference, results from Study II indicate that no practical significant difference was present between cows in the CLH and those in the WLH — e. g., parity 2 cows of the Finnish Black and White breed calving in winter 1997 were predicted to produce 7337 litres in CLH and 7540 litres in WLH. Although I do not have confidence intervals for these estimates, a practically significant positive association of keeping cows in a CLH seems unlikely.

4.1.3 Comparison of fertility

In Study III, the number of days-to-first-service, the first-service-conception risk and the repeated-service-conception hazard of cows kept in approximately 40 cold and 120 warm loose-housing systems were compared. The study population comprised cows that calved during the indoor-periods of 1996 and 1997. In the study, a statistically significant difference for the days-to-first-service (Table 4.1) and for the repeated-service-conception hazard could not be demonstrated (Table 4.2 on the facing page). A statistically significant difference was, however, observed for the first-service-conception risk(Table 4.3 on the next page): compared with cows in WLHs, those in CLHs had a 6% lower risk of conceiving (risk difference). Nevertheless, the significance of the difference was influenced by several farms (mostly CLH) (Figure 4.3 on the facing page). Based on the assumption that a 10% shorter or longer time-to-first-service, a 10% higher or lower first-service-conception risk and a 10% higher or lower repeated-service-conception hazard would result in a practically significant difference, findings in Study III can be used to almost rule out any difference in the time-to-first-service (there is a small chance of cows in WLHs having a shorter period, $0.1 > P > 0.05$). The study also rules out any positive effects of the CLH on cows' first-service-conception risk. It can not, however, be used to rule out practical significance between the type of loose-housing and the repeated-service-conception haz-

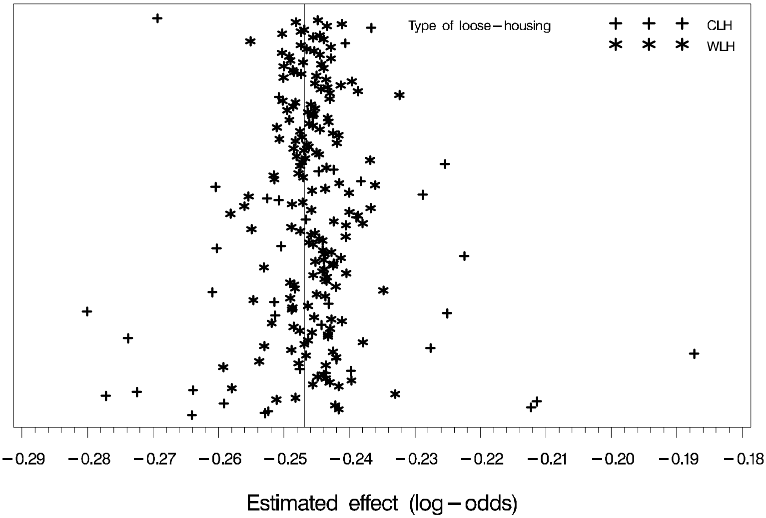

Figure 4.3: Influential farms in testing the effect of type of loose-housing on first-service-conception risk. Each symbol marks the result of the comparison with one farm deleted from the data set. Symbols to the right of the reference line indicate results that are not significantly different from 0 ($P > 0.05$).

Table 4.2: Proportional probability model for the repeated-service-conception hazard in cold and warm loose-housing systems (adjusted for number of days from previous insemination) (Finland, 1996 and 1997; Study III).

Type of loose-houseing	Hazard ratio	P-value	95% CI
Warm loose-housing	1.11	0.51	0.8 to 1.56
Cold loose-housing	1	-	-

Table 4.3: Logistic regression model for the first-service-conception risk in cold and warm loose-housing systems (adjusted for parity and days in milk) (Finland, 1996 and 1997; Study III).

Type of loose-houseing	Odds ratio	P-value	95% CI
Warm loose-housing	1.28	0.05	1.00 to 1.64
Cold loose-housing	1	-	-

ard. The most likely values nevertheless indicate a negative effect of the CLH on the first-service-conception risk and on the repeated-service-conception hazard.

4.2 *Effects of breed of cow on health*

In Study IV, the disease incidences of $\approx$ 72000 Finnish Black and White cows and $\approx$ 200,000 Finnish Ayrshire cows calving in the year 2000 were compared. The study population was stratified by housing type (loose-housing systems and tie-stalls). Compared to Finnish Ayrshire cows, Finnish Black and White cows kept in tie-stall systems had a statistically significant higher incidence of all studied diseases except ovarian disorders; ovarian disorders were observed significantly more often in Finnish Ayrshire cows (Figure 4.4 on the next page and Figure 4.5 on page 54). In loose-housing systems, the estimated ratios were similar to those for cows in tie-stalls, with the exception that for early mastitis and metritis the differences were no longer statistically significant.

None of the associations between cows' breed and incidence of any of the diseases would be practically significant for a farmer of a median-sized farm with a 'typical' seasonal calving pattern if only one or more additional cases every year would result in a practically significant difference. On the other hand, all breed differences, except the risk ratio for high SCC, are practically significant for breeding organizations in a least some of the different categories of parity and calving season if a 20% increase or decrease in incidences is assumed to result in a difference.

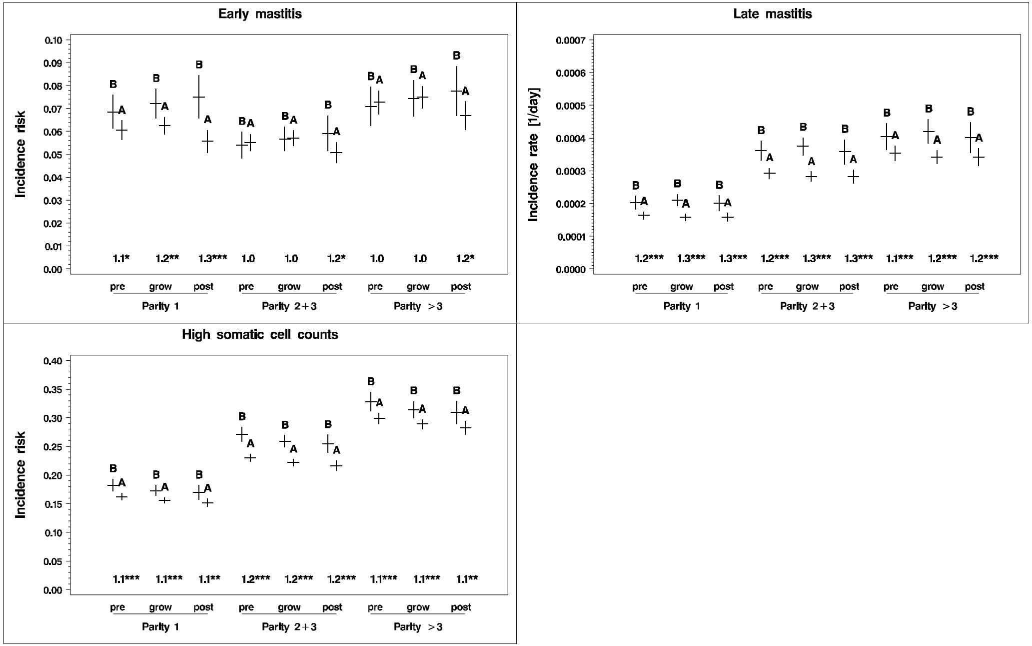

Figure 4.4: Incidences (+95% CI) for early mastitis, late mastitis and high somatic cell count for Finnish Black and White cows (B) and Finnish Ayrshire cows (A) in tie-stalls, stratified by calving season (pre-growing (pre), growing (grow) and post-growing (post)) and by parity (Finland, 2000). The numbers in the figures are estimated risk ratios or rate ratios, together with stars denoting the significance of the estimates ($* \equiv P < 0.05$, $** \equiv P < 0.01$, $*** \equiv P < 0.001$). Estimates are slightly different from those in the article because for the predictions in this figure, the full model was used.

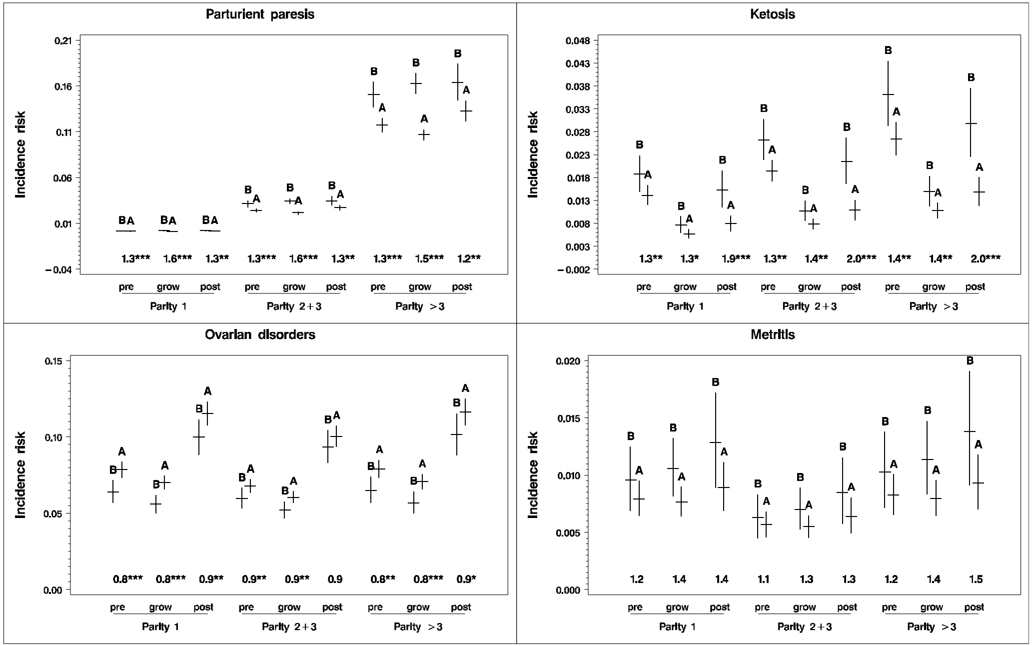

Figure 4.5: Incidences (+95% CI) for parturient paresis, ketosis, ovarian disorders, and metritis for Finnish Black and White cows (B) and Finnish Ayrshire cows (A) in tie-stalls, stratified by calving season (pre-growing (pre), growing (grow) and post-growing (post)) and by parity (Finland, 2000). The numbers in the figures are estimated risk ratios, together with stars denoting the significance of the estimates ($* \equiv P < 0.05$, $** \equiv P < 0.01$, $*** \equiv P < 0.001$). Estimates are slightly different from those in the article because for the predictions in this figure, the full model was used.

V

Discussion

5.1 Results

The aim of this work was to estimate the effect of two strategies in dairy production — keeping cows in a cold loose-housing system and keeping Finnish Black and White cows — on cows' health, production and reproduction. The results show that, yes, there are effects of both strategies on cows' health, production and reproduction, but they are most likely not so large as to be of major concern to a farmer of a median-sized dairy farm ($\approx$ 16 cows) in Finland.

In the comparison of the two loose-housing systems, the relatively small effect of housing type was surprising to me — I would have expected that the cold winter climate affects the cow either directly or indirectly through malfunctions of the farming systems. By contrast, the large variation in cows' health, fertility and production between farms, independent of the type of loose-housing, was expected. The higher incidences for mastitis, metritis, paresis and ketosis in Finnish Black and White cows was hardly surprising to me, given the poor health reputation of Black and White cows. Nevertheless, these differences were quite small and only reached significance because of the large study population. The higher incidences of ovarian disorders in Finnish Ayrshire cows were, however, unexpected.

Several studies (observational studies as well as clinical trials) have shown similar results in the estimation of the effect of type of loose-housing on cows' health, production and fertility. Most of them have shown no (statistically significant) effect of the CLH; one has demonstrated a beneficial effect of the CLH on reproductive disorders, mastitis and milk yield (Table 1.8 on page 17). In the estimation of the effect of cows' breed, different effects have been reported. In contrast to my study, lower incidences of parturient paresis and ketosis have been found for Swedish Friesians than for Swedish Red and Whites; in agreement with my study, higher incidences of mastitis, tramped teats, dystocia and retained placenta (the latter two being component causes for metritis) have been associated with Swedish Friesians

(Table 1.9 on page 19). The observed breed-effects that I found in Study IV were largely the same as those in Study I.

To explain the observed effects and to understand why other studies have found discrepant results, clarifying the mechanisms underlining the effects of type of loose-housing and cows' breed would be beneficial. For Studies I–III, it seems to be a reasonable starting point to assume that the effects were caused by micro-climatic conditions because this is the main difference between these two types of loose-housing — indeed, it has been used to define exposure in the comparison of CLH and WLH. Clinical trials in which cows were exposed to different temperatures have shown that exposure to low temperatures can have detrimental effects on their health (Fox and Norell, 1994) and production (Christopherson and Young, 1986) — effects that might have been reflected in the (non-significant) lower milk yield and lower first-service-conception risk of cows in CLH.

The effect of micro-climatic conditions in CLHs on the cows might be related to a shortage of energy during the first part of lactation, which in turn might be related to the lower digestibility of feed. Low digestibility in cold environmental temperatures might be caused by an increase in the passage rate of digesta (Christopherson and Young, 1986). Additionally, low digestibility in CLHs could be caused by the frozen silage fed in mid-winter (in WLHs, frozen silage is thawed before feeding). Lower feed digestibility could lead to a larger negative energy balance at peak milk yield, which has been related to lower milk yield, lower fertility and higher disease incidences. Nevertheless, in case of shortage of energy during the first part of lactation, a longer period from calving to first insemination would have been expected (Suriyasathaporn et al., 1998), but this could not be demonstrated in the study.

Compared with cows in an experimental climatic chamber, cows in a CLH are normally acclimatized to low temperatures (for example, they have considerable ability to adjust coat depth according to how hot or cold they sense the environment to be; Webster 1993), which might be one of the reasons for the rather low effect of the CLH. Furthermore, farmers of a CLH seem to be able to adapt their management to the cold temperatures (for example, they can reduce the effect of the cold floor by supplying a sufficient amount of bedding (Table 3.4 on page 42)). Cows in a CLH are not affected by temperature alone but also by other components of the micro-climate. For instance, cows' heat loss is synergistically affected by high humidity in combination with low environmental temperatures and air movement

(Webster, 1974) — the effects of the 'milder' winter climate in Denmark, with a higher humidity and a stronger wind, might be more detrimental to cows' health, production and fertility than the very cold but dry conditions in Finland's winter. Indeed, the higher incidence of mastitis and lameness in Danish WLHs was probably caused by the higher humidity, present in a WLH that is not sufficiently ventilated (Konggaard and DeDecker, 1984). Finally, climate is not the only difference between CLHs and WLHs that affects the cow and the farmer: a CLH is a system that is (in most cases) modified to cope with the effect of the climate — slatted floors, for example, are rarely seen in a CLH, while deep bedding systems are rarely seen in a WLH. Both slatted floors (Barkema et al., 1999) and deep bedding systems (Fregonesi and Leaver, 2001) are related to the incidence of mastitis.

The effect of the CLH on response variables was similar to that of other housing variables reported in the literature (e. g., the use of an electrical cow-trainer (Oltenacau et al. 1998) or keeping cows in a loose-housing system as opposed to a tie-stall (Valde et al., 1997)). It was lower than the effect of several 'cow-level' variables, such as parity (on, for example, the cows' risk of parturient paresis (Rajala and Gröhn, 1998)) or cows' having had a different disease earlier in lactation (Correa et al., 1993).

Understanding the effect of cows' breed on susceptibility towards diseases is more complicated. Breed effects are inherited traits of the cows' unspecific, paraspecific or pathogen-specific immune system. These inherited traits are not at all stable over time — within only a few years, rapid breeding progress in Finland has changed the 'traditional' Finnish Friesian to a 'modern', high-producing Holstein Friesian (Lidauer and Mäntysaari, 1996). Conventional wisdom (and research, Raijala and Gröhn, 1998) has it that higher-producing cows are more susceptible to diseases (thus the term *production diseases*) partly because of the large amounts of body reserves that they have to mobilize to sustain a high milk yield. It might be speculated, therefore, that the higher disease incidence of the Finnish Black and White breed is merely a side-effect of the cows' higher milk yield. Nevertheless, several studies have shown that the relationship between milk yield and disease incidence is not straightforward — not even within the same breed (Erb, 1987, Gröhn et al., 1995). Because milk yield is an intermediate variable in the evaluation of the effect of breed on disease incidence, the variable does not qualify as confounder and should not be controlled for in the analysis.

The effect of breed on susceptibility towards diseases could also be due to different management of Finnish Ayrshire and Finnish Black and White cows. For example, a farmer who introduces a Finnish Black and White cow into her Finnish Ayrshire herd introduces a relatively large cow into a cow house that was designed for the smaller Finnish Ayrshire.

5.1.1 Practical significance of results

Practical significance of a change in cows' risk of disease, milk yield or fertility is very much dependent on the subjective interpretation of negative effects of diseases and bad fertility on cows' welfare and longevity and on the farmer's income. For the farmer, based on the results from this and other studies, a change in the type of loose-housing will not result in a practically significant increase or decrease in disease, milk yield or fertility. Nor will a change in breed bring about a practically significant increase or decrease in disease. This is due to (1) the relatively low estimated effects of the type of loose-housing and the cows' breed (as evaluated from the range of possible population parameters), (2) the relatively low incidence of the diseases and (3) the small herd sizes in the study population. Indeed, for the farmer of a median/sized farm, a change in the type of loose-housing or in cow breed is very unlikely to result in even one additional diseased cow a year.

On a national level, however, the changing cow breed from Finnish Ayrshire to Finnish Black and White cows would most likely result in a practically significant increase in the risk of several diseases. The difference between the two parts of the study is that it is very unlikely that a large number of farmers will change to a CLH (economic benefits are probably not *that* large and working conditions might be worse in winter[1]) — the number of cows in the target population to be affected by changes in disease incidence is therefore low. It is much more likely though that more farmers in the target population will change from the Ayrshire to the Black and White breed, according to the annual statistics from Finland and other European countries, where the Black and White cow is becoming virtually the only milking dairy breed. For comparison, another risk factor that may have an impact on large numbers of cows in Finland (and the rest of the EU) is the use of bovine somatotropin (bST) in dairy farming. The increased risk of mastitis from the use of bST has been estimated to be between 15% and 79% (Section 1.2.1.1 on page 3) — approximately the same increase in risk as that estimated in Study IV for the change of breed from Finnish Ayrshire

[1]In the questionnaire (Table 3.4 on page 42), many farmers indicated that humidity and air quality in CLH were better, but temperature and light were worse.

to Finnish Black and White, which was between 14% and 51%, depending on the parity, calving season and type of housing. The use of bST was banned in the EU for welfare reasons — it seems not to be a production method that the public wants (see Section 1.1 on page 1). Does the change in breed meet the public approval[2]?

The study populations in all four studies were restricted to cows in lactation. Non-lactating cows (calves, heifers) and bulls were not included because the database that we have used does not include treatments and mortality for dairy cows during this period or for beef cattle at any time in production. Excluding these animals was unfortunate because effects of climate and breed on morbidity and mortality in those animals are known (e. g., Heinrichs et al., 1994), and their health and welfare are important variables if we want to meet the objectives of the EU. Indeed, calves' health and welfare might be a problem in CLH — often, they are kept in old (insulated, but too cold and humid) barns with insufficient ventilation and heating.

Similarly, the response variables were restricted to five diseases, although several other diseases in the target population might have also been important. Lameness would have been a good response variable to include because there is a high prevalence of lameness in the Finnish dairy cattle population (Jankko et al., 2004), and the disorder has a large negative impact on farm economy and cow welfare (Anonymous, 2001). Moreover, evidence suggests that the prevalence of lameness is affected by climate and cows' breed (Thysen et al., 1985; Alban et al., 1996). Nevertheless, in contrast to the other diseases in the study, veterinary treatments of lameness are a poor indicator of actual disease prevalence since most cows with lameness go untreated (Webster, 1993). A study based on veterinary treatments alone would have had an overly large potential for bias.

Finally, infectious diseases of Lists A and B of the OIE were not included because Finland was free of most of them. While cows' breed is probably not a risk factor for contracting any of the List A and B diseases, being confined to a CLH might be, as CLH are probably more difficult to keep 'closed' in an outbreak.

[2]One might also ask whether the 'diversity in forms of agriculture', an objective in the EU policy, is maintained when almost all cows are Finnish Black and Whites.

5.2 *Materials and methods*

In the aims of the study (Section 2 on page 27) it was stated that. . . :

> To obtain internally as well as externally valid estimates, I had to find valid ways of estimating disease incidence, milk yield and fertility in the target population and then valid ways of comparing these estimates between cows in the two loose-housing systems or between cows of two breeds.

5.2.1 Measuring response

Measuring the disease incidence turned out to be very controversial. Measuring the lactational incidence risk (LIR) in Studies I and IV, as recommended (Kelton et al., 1998), was not possible because a large number of registered lactations were incomplete (305 days) — cows were either culled, sold, lost-to-follow-up before reaching 305 DIM, or (especially in Study I) the indoor period ended before the cows completed their lactations. In calculating the LIR, these observations would have had to be *excluded* (see Section 1.4 on page 20), which is far from optimal — not only would it render the study population to a size much too small to draw inferences from, but excluding them could also lead to selection bias because cows that were culled during lactation ($\approx$ 30%) probably had been at high risk of contracting a disease[3] (e. g. cows with subclinical mastitis are culled *without treatment* towards the end of their lactation and are not recorded as diseased). To avoid these problems, the LIR could be calculated as the number of cows that contracted the disease divided by the sum of calvings (Gröhn et al. , 1990) — but this calculation invariably leads to an underestimation of the 'true' incidence risk. To calculate a more valid incidence risk, two alternatives remain: measuring the hazard of disease in a survival analysis model or using a shorter period-at-risk (classifying cows as healthy, even though they contract the disease after the period-at-risk ends). Measuring the hazard of disease was tempting, but the relatively low disease incidence caused almost all observations to be 'right-censored', and therefore, results from survival analysis would probably have become unreliable (because all censoring has to be 'non-informative' — an assumption that is almost impossible to meet when

[3] In survival analysis, this is known as *informative censoring* and is subject to discussion — in logistic regression, it is typically ignored.

so many observations are censored). Measuring the cows' risk of contracting the disease in a shorter time period sets limitations on extrapolation of results to the target population — whether the type of loose-housing or the cows' breed causes the cow to contract any disease but late mastitis more often in late lactation can not be deduced from my study. Interestingly, in both Studies I and IV, the comparison of the incidence of metritis gave unexpected results — in Study I, I found an unexpected interaction with cows' breed, and in Study IV, I could not find any significant correlation in the loose-housed cows. A reason for these unexpected results might be that my measure of incidence was not optimal: in Study IV I 'lost' many cases that occurred after the end of the 19-day period-at-risk.

Measuring the cows' fertility in Study III was complicated as well. While the measures of the period time-to-first-service and first-service-conception risk were relatively conventional, measuring the repeated-service-conception hazard was typically only of human time-to-pregnancy studies (Weinberg and Wilcox, 1998) — in dairy fertility studies, this period is most often measured as 'first-service-to-conception' or alternatively as 'number of services per conception'. 'First-service-to-conception' is a continuous measure and therefore problematic to use because the probability of conception is not continuous — a cow can only conceive during short parts of its estrus cycle (and only, when inseminated at the right time). The 'number of services per conception' has the disadvantage that only cows that conceive during the period-at-risk can be included in the study. Measuring the repeated-service-conception hazard solves both problems — it is a discrete measure which includes censored observations.

5.2.2 Cows with Ayrshire risk factors

Part of the difficulty in understanding the breed effect stems from a problem in using the 'counterfactual' argument (see Section 1.4 on page 20) — to investigate the effect of breed, Finnish Ayrshire cows were compared with Finnish Black and White cows, making the assumption that a Finnish Ayrshire cow is a Finnish Black and White cow with 'Ayrshire risk factors'. Exposure and non-exposure to breed does not make sense.

5.2.3 Internal and external validity

5.2.3.1 Selection bias

Selection bias occurs when the relation between the study variable and the response variable is different for subjects participating in the study and those who theoretically would have been eligible to participate (see Section 1.4 on page 20). Selection bias in my study might have occurred because of the effects of winter calving, exclusion of cows or farms from the study population and missing values.

5.2.3.2 Exclusion of pasture time

When is a cow exposed to a type of loose-housing? In the study populations of Studies I–III, $\approx$ 30% of cows were put out to pasture during the summer, either all day round or only during the day time. Are they exposed to type of loose-housing also during pasture time? In a study on the effect of a farming system that includes keeping the cows in a CLH part of the time, these cows would be exposed. However, in a study that evaluates the effect of a CLH, these cows would *not* be exposed.

Because my research was directed at evaluating the effect of type of loose-housing, observations from cows on pasture were excluded. Excluding cows during the pasture time resulted certainly in a clearer picture of the relationship between type of loose-housing and the cows' risk of disease and fertility, because during the pasture time, the effect of the type of loose-housing would have gradually been diluted in cows that went 24 hours on pasture and would have been distorted in cows that were exposed to the type of loose-housing only during night time or for 24 hours. Including cows calving on pasture and then later-on correcting for effects of the pasture time in the model was not possible for the same reasons — effects of the pasture time are certainly not homogenous in the different pasture strategies. Unfortunately, excluding these observations has some disadvantages. Firstly, it restricts the period-at-risk to short intervals, resulting in many cows not having been observed through the full lactation. Secondly, long-term effects of both being exposed to pasture and being exposed to the loose-housing can dilute the effect of the type of loose-housing. Thirdly, the study population becomes much smaller, with the same number of farms but fewer observations per farm. And finally, results from the study do not tell us how many more cases *per year* a farmer will see. In Study II, an additional disadvantage forced me to include pasture time: the full lactation curve could not be statistically evaluated using test-day milk yields from only the short indoor periods.

The effects of type of loose-housing are probably largest during the indoor (winter) period, when the differences in the micro-climates of CLHs and WLHs are greatest. Therefore, the estimates of calculated effects, excluding observations from cows on pasture, should be higher than the actual 'year-round' effects. Nevertheless, if confined during the outdoor period, cows in a CLH could also be exposed to heat stress, especially cows in greenhouses.

5.2.3.3 Exclusion from the study population

In Study I–III, selection bias could have occurred had the relation between type of loose-housing and response variables been different for cows on farms where the farmer returned the questionnaire than for cows on farms where the farmer received the it (76% of questionnaires were returned). Bias from the non-responders should, however, be negligible since no obvious deviations were noted in comparing information from non-participating farms with information from participating farms[4] (Figures 3.2 on page 33–3.5 on page 36).

A similar bias could have been introduced if the relation between cow breed or type of loose-housing and the response variables was different for cows on farms that were participating in the disease recording system and farms that were not ($\approx$ 77% of dairy farms were participating; Saloniemi and Kulkas, 2001). Compared with cows on participating farms, other cows have been reported to produce up to 2000 kg less milk per lactation and to have a 4-5% higher non-return rate to first service (Rautala 2003, personal communication). Nevertheless, bias from different participation should be low because there is no reason to suspect that the effect of type of loose-housing and cows' breed is different on farms that were participating and farms that were not. Bias could have occurred if there was an interaction of type of loose-housing with milk yield on cows' disease incidence or fertility (e. g., if low-producing cows or cows on low-producing farms were less affected by the conditions in the CLH than high-producing cows), or if there

[4]The questions arises whether using information from non-participating farms was ethically correct because non-participation could be interpreted as the farmer wanting to avoid his data being used in the research.

was an interaction of type of loose-housing with the herd size on any of the response variables.

Finally, bias could have been introduced if the relation between cows' breed or type of loose-housing and the response variables was different for cows on farms where the type of housing (tie-stall or loose-housing) was registered at the Finnish data processing centre and cows on farms where it was not registered (housing type was registered for $\approx$ 40% of farms). This bias should be low, however, because there is no reason to suspect that the effect of type of loose-housing and cows' breed would be different on farms where the type of housing was not registered.

5.2.3.4 Information bias

The response variables in Studies I and IV were (recorded) veterinary treatments of five disorders (Section 3.2 on page 30). Figure 5.1 on the facing page demonstrates that while the information from the database should be accurate regarding the actual treatment of the disease (depending mainly on the veterinarians' motivation to record treatments), it is probably not accurate regarding the true incidence of diseases. In section 3.2 on page 30 I have stated that misclassification should not have not caused serious bias in calculating the odds ratio because the data were assumed to have high specificity. High specificity was assumed because both farmers and veterinarians are experienced in diagnosing any of the five relatively broad disease complexes (Table 3.2). Additionally, only the veterinarian is entitled to fill-in disease information into the herd book. Nevertheless, studies from Norway and Denmark show that the specificity of veterinary recorded cases of ketosis can be low (Simensen et al., 1990) and non-reporting of veterinary treatments can lead to biassed estimates of true incidence rates of mastitis (Bartlett et al., 2001). Non-reporting of veterinary treatments was suspected in the records from a few farms with no disease record at all during the study periods of studies I and IV. Nevertheless, since the study periods were relatively short, disease incidences for most diseases low and farms quite small, it seems not impossible that a farm really had not treatment for any disease during that time. A random veterinary effect could have been included into the analysis to adjust for 'veterinary-bias' and for correlation between cows treated by the same veterinarian, but including additional random effects to the model would most likely have caused numerical problems.

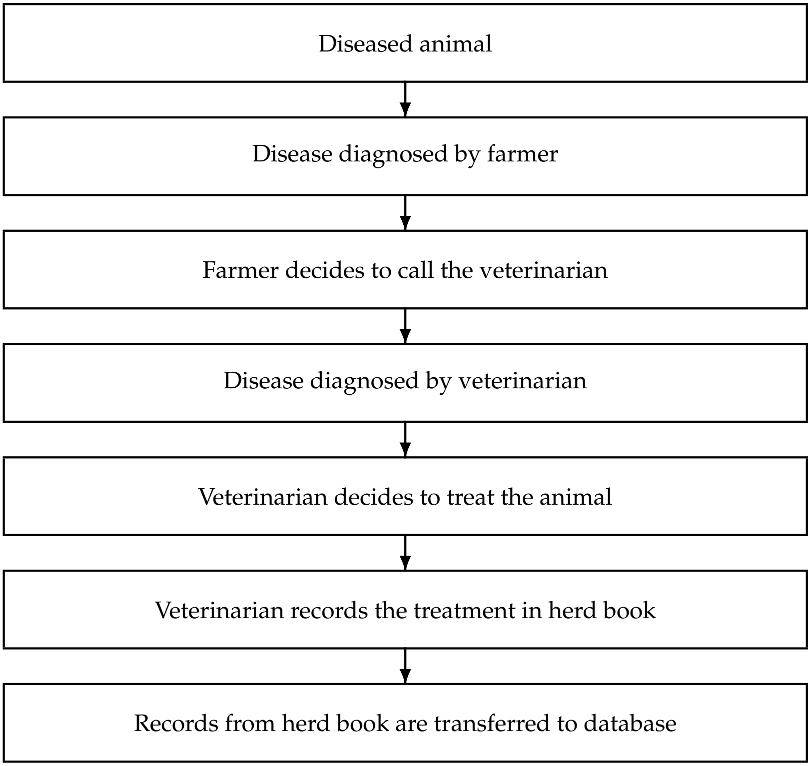

Figure 5.1: Flow of information from the diseased animal to the recorded veterinary treatment

5.2.3.5 Missing values

Some farms as well as cows have been excluded from the study population, due to missing information on a response variable, a study variable or a confounder — the coding 'missing values' was included only in Study I. This coding caused some variables to be misclassified as confounders ($P < 0.1$) in the model building process because cows in that category were different from cows in any of the other categories[5]. This result illustrates the problem in including a 'missing value' level: Cows with missing values often do not form a summary group somewhere between the other groups.

Two alternatives to coding 'missing values' have been developed — leaving out observations with missing values (the default in most statistical software programs; used in Studies II–IV) or 'imputing' a value based on other observed characteristics of the cow. Excluding observations with missing values might introduce selection bias if the relation between cows' breed or type of loose-housing and the response variables was different for cows with and without missing information. For example, the relation between type of loose-housing and cows' disease incidence might have been different in cows for which parity and breed were registered and those for which they were not (culling or selling of a cow could be related to some of the missing information). Excluding observations with missing values can additionally cause the study population to become too small. Excluding observations with missing values was therefore not a good alternative to coding missing values in Study I because several farms had missing values on some of the (potential) confounders. On the other hand, in Studies II–IV, it was probably the best alternative since only variables at cow-level were included, and the number of missing observations in these variables was sufficiently small to prevent serious selection bias.

Statistical imputation of missing values was not performed because the processes that led to an observation having a missing value were not uniform (King et al., 2001). Several variables were 'missing' because of *branching questions* in the questionnaire — questions that could only be answered by farmers of a subpopulation of the study population (for example, questions about cubicle design cannot be answered by farmers who have a deep-bedding system). In that case, new variables with many levels were constructed (e. g., 'farm with cubicle system and mats on the floor of the cubicle'); too many lev-

[5] In this case, the variable was excluded from the model building process.

els with too few observations were sometimes constructed, rendering some statistical results unreliable.

5.2.3.6 *New barns in the study population*

Another bias could have been introduced in Studies I–III by including new barns in the study population from the first month of production onwards. This bias originates from cows and farmers of new barns having almost inevitably to go through a phase of getting used to the new facilities. During this phase cows might show higher incidences of several diseases (e. g., mastitis; Saloniemi and Näsi, 1982) and might also show (consequently?) a drop in milk production. Because almost 60% of the CLHs started production during the study period, the bias might have influenced the estimates for the effect of type of loose-housing. Indeed, evaluation of this bias in Studies II and III showed that cows during their first year in a new CLH produced about 100 l less milk ($P = 0.07$) and had a lower repeated-service-conception hazard ($P = 0.03$).

Nevertheless, 'new' CLHs were not separated from 'old' CLHs when drawing inferences because the two CLH groups would have been too small. In addition, 'new' CLHs are not only unfamiliar to the cow and the farmer but also introduce modern 'up-to-date' methods to the group of loose-housing systems — leaving them out of the study population would have introduced more bias by artificially aging the group of CLHs. Finally, correcting for the effect of being 'new' in the analysis was not possible, because being 'new' and being a CLH was highly correlated.

5.2.3.7 *Generalizability*

Given the caveats above, results from this study should be applicable to the target population (Section 3.1 on page 29). Results from the comparison of the two types of loose-housing seem to also be applicable to farms outside Finland because other countries with relatively similar production conditions (e. g., Denmark and the Czech Republic) have reported similar findings (Table 1.8 on page 17). Generalization of the results to dairy populations outside the target population is, however, problematic since different herd structures (e. g., herds with several thousand cows in a CLH), different feeding regimes (e. g., feeding maize) or different breeds could have an influence on the effects produced by the effects of the type of loose-housing.

The *mean* health, production and reproduction in both loose-housing systems is apparently similar. Several farms of both types have reported very good health, production and reproduction, but several farms of both types have also reported relatively poor health, production and reproduction (Figures 3.2 on page 33, 3.3 on page 34 and 3.6 on page 37). Good, healthy production with either of the loose-housing systems is possible, and it is equally possible to fail with both systems — an observation that has also been presented before (Tirkkonen, 1997).

To avoid having to express results from different farms as a mean, Studies I–III could have been planned and conducted as an experimental study. Indeed, most studies examining the effect of type of loose-housing have been experimental studies (e. g. Bešlin, and Anojčić, 1979; Konggard, 1980; Konggaard and DeDecker, 1984), avoiding not only the 'farm effect' but also the problem of dealing with several confounding factors. Nevertheless, these studies were normally restricted to rather small study populations, which were too small to draw inferences from. In addition, experimental studies often have a relatively narrow target population — that type of loose-housing has no effect on cows' health under research conditions does not say much about the effect under normal conditions.

5.2.4 Statistics

5.2.4.1 Model selection

Logistic regression was used to test incidence risks (I and IV) and first-service-conception risk (III), Poisson analysis to test incidence rates (I and IV), linear regression to compare cows' milk yield (II) and, finally, survival analysis to compare the days to first insemination (III) as well as cows' repeated-service-conception hazard (III). While the use of linear and logistic regression was rather unproblematic, the use of Poisson analysis for cows' risk of contracting late mastitis in Studies I and IV was not optimal.

The major advantage of Poisson analysis is that observations from cows that have not been observed through the entire risk period (305 days for 'lactational' incidence) can be used — because the maximal period in Study I (from the beginning of the indoor period in 1996 to the end in 1997) was 242 days, none of the observations continued for 305 days. An additional advantage is that all cases during the lactation can be analysed, which makes a lot of sense, because the second case and other subsequent cases are likely similarly affected by the type of loose-housing and cows' breed and have an equal impact on cows' welfare and farmer's economy. A disadvantage of Poisson analysis is the assumption that cows' risk of contracting the disease was constant over the risk period. Because this assumption is clearly violated in the Poisson analysis of the incidence rate of mastitis, the first 14 DIM were analysed separately (in logistic regression). While splitting the risk period decreased the bias from the violated assumption (even after 14 days, the risk of contracting mastitis in early lactation is slightly higher than in later lactation; Østerås et al., 2002), the number of cases for late mastitis became quite low (Figures 3.3 on page 34 and 3.5 on page 36). The Poisson distribution does not approximate this low incidence rate well; *under-dispersion* was obvious in the results from the models for late mastitis. A zero-inflated Poisson model, which would probably better fit the data, makes the assumption that two different processes are simultaneously occurring — a Poisson process and a process where the animals would not be at risk. This assumption is, in my view, not tangible because the only reason why animals might not have been at risk of treatment was that they were intended for slaughter, and this fraction of animals was too small to explain the under-dispersion.

In Section 1.4 on page 20 a confounder was defined as a variable that at the same time a) is a risk factor in unexposed individuals, b) is correlated with the study variable and c) would have been controlled for in a clinical trial. However, in determining confounding (Section 3.5.2 on page 44) potential confounders were only tested for a correlation with the response variable (basically, if (a) is true). Although this testing for confounding is a standard procedure[6], it is nonetheless controversial. One reason is, that statistical significance is dependent on sample size — using only this one test, I might have missed important confounding factors in Studies I–III because the study population was too small. A second reason is that in using a 5% error margin *every* test bears a 5% risk that a variable is misclassified as confounder — testing for, say, 20 variables, as in Study I the probability that I have wrongly included a variable as a confounder is very high. A third reason why this testing for confounding is controversial is that it ignores points (b) and (c). For example, cows with a history of low fertility are problematic in the estimation of the herd fertility because they often are culled and not inseminated (causing the estimated herd fertility to be too high). Is the

[6] Indeed, several tests for confounding have been performed only because of pressure from the journal's referees — several more have been demanded.

herd-level culling ratio therefore a confounder in the estimation of the first-service-conception risk? Point (a) is fulfilled since the culling ratio is correlated with the first-service-conception risk in the WLH (defining CLH as exposure). Point (b) might be fulfilled because the culling ratio could be correlated with the type of loose-housing — indeed, the percentage of cows culled for infertility of all cows culled was about 4% in WLH and 2% in CLH. Given that the total percentage of cows culled in both systems is the same, this is twice as many cows culled for infertility — or a risk difference of 0.02. While the first measure of correlation (risk ratio) indicates a correlation (although most probably not statistically significant)[7], the second measure surely does not. But even if (a) and (b) were fulfilled, point (c) is not. In a clinical study on the effect of a CLH, culling for infertility would probably not have been controlled for — it is an *intermediate variable*. Similarly, milk yield is not a confounder in the estimation of the association of breed with disease incidence, because milk yield is a characteristic of the breed. Nor is age at first calving a confounder in the estimation of the association of the type of loose-housing with cow fertility, because age at first calving is certainly affected by the type of loose-housing.

5.2.4.2 Extra-correlations

Correlations between observations were modelled using random effect models (I and III), random coefficient models (II) and covariance pattern models (IV). The correlation in Study I between cows of the same farm was modelled with a random effect model, which might have lead to biassed estimates. Estimates for the variance for the random herd effect in Study I were between 0 and 3.5 (in the Poisson model for late mastitis and the logistic regression model for ketosis, respectively). Estimated variances of farm effects of zero and > 1 seem dubious to me, although I do not have values for comparison. Indeed, these estimates might have been biassed because there were many farms in the study population that had not observed any case (for ketosis, e. g., more than 75% of farms (3.2 on page 33)), and random effect models with uniform effect categories can give unreliable results (Brown and Prescott, 1999). In the random effect models in Study I, extra-binomial and

[7]Testing whether the percentage of cows culled for infertility of all cows culled was significantly different between CLH and WLH was not useful here because (a) I have not designed the study to test the difference (indeed, I suspect a large amount of misclassification in the records) and (b) it does not help in the evaluation whether or not it is a confounder.

extra-Poisson variation was observed and allowed for. This extra-variation indicates that some non-measured (latent) variables at cow-level existed in addition to the (latent) variables at herd-level (and, again, it probably indicates a problem with the Poisson model).

The correlation in Study IV was modelled with a covariance pattern model to avoid the potential bias from farms with zero incidence during the study period (and because computational resources were restricted). Estimates for the (constant) correlation in the logistic models were between 0.01 (metritis) and 0.13 (ovarian disorders). Model fit (assessed from the extra-dispersion scale) was fair in the logistic regression models ($\approx$ 0.95), but again, under-dispersion in the Poisson models was evident.

Interpretation of the estimated random effect or the estimated extra-correlation is not clear. *A* farm-effect or *a* constant correlation between animals of the same farm is estimated in the models. Nevertheless, on some farms, the *farm effect* might impact on different groups of cows differently (say, high-producing cows are all at higher risk because the quality of the feed is insufficient to allow for high production) — what is the interpretation of the individual farm effect? Is there *any* farm effect that affects all of the cows similarly? Another problem in interpreting the extra-correlation in the covariance pattern models that I have used is that the correlation is assumed to be the same between cows on all farms in the study populations (say, 0.13 for ovarian disorders). Nevertheless, shouldn't there be a higher correlation between cows of farms where farmers do extremely well or poorly (say, the farmer does so poorly that all cows contract the disease), and a lower correlation between cows on 'mean' farms? Different correlation structures might be available but have, to my knowledge, not been used so far for the correction of farm effects.

Interpretation of the estimated main effects is problematic, as well. Estimated effects from random effect models are 'subject-specific', while estimates from covariance pattern models are 'population-averaged'. While this difference is not a problem in linear regression (both estimates are the same), in logistic regression, the two approaches lead to different estimates (estimates from random effect models will always be higher; Twisk, 2003). In a study like ours, in which the relationship between a dichotomous response variable and several other predictor variables was studied, 'population-averaged' models probably give the most 'valid' results. Moreover, 'population-averaged' models are better implemented in statistical software than 'subject-specific' models (Twisk, 2003).

To correct for the correlation between test-day records of cows and cows of the same herd (IV), a random coefficient model was used — not the more typical combination of a random herd effect and an (autoregressive) covariance pattern (e. g., Rajala-Schultz et al., 1999b). Random coefficient models have the advantage that they directly model the lactation curve of each of the cows in the study population. Furthermore, test-day records can be used from any day in lactation, which is probably their biggest advantage over covariance pattern models[8]. Unfortunately, the model became very memory-consuming (the final model took over 4 CPU-hours on a Hewlett-Packard 9000/785 workstation). Therefore, it was impossible to add any confounding factor apart from the cow-level variables of breed, parity and calving season, or to model a residual covariance structure.

5.2.5 Model diagnostics

Model diagnostics in mixed models is relatively complicated — not even the definition of a *residual* is straightforward (Verbeke and Molenberghs, 2000). Nevertheless, several diagnostics should be equally applicable in both mixed and conventional models, and the fit of my final models has been checked in several ways to ensure that the estimates from the models were valid (see original articles). Because the number of farms in the study population was relatively low, the fit of the final models in Studies I–III might have been compromised by a few farms having a large influence on the estimates. Figures of *influential farms* in Studies I and III nevertheless showed that for most models deletion of single farms from the study population had no major effect. The only exception was the result from testing the influence of type of loose-housing on first-service-conception risk (H_03_2) — while the effect of type of loose-housing including all farms was significant, deletion of some of the farms caused the estimate to no longer be significant (Figure 4.3 on page 51). Nevertheless, this *change in significance* is not an indication of poor model fit because the estimated odds ratio for the effect of type of loose-housing only varied marginally (0.76 to 0.83) — the P-value from the model including all farms was only slightly below 0.05, and deleting some farms increased the value to just over 0.05.

[8] Although test-days in my study population were quite regularly spaced (at 30-day intervals), the first test-day in lactation was randomly spread (any day between 5 and 35 days after calving (during the first 5 days, milk yield is normally not tested)).

VI

Conclusions

Conclusion I: The development of CLH in dairy production in Finland most likely does *not* pose any threat to the objectives of the EU. Differences in health, milk yield and fertility are low, and should, thanks to relatively low disease incidences, not be of concern to farmers thinking about changing to a CLH. Because the total number of cows kept in a CLH in Finland will probably never be very high, the number of additional cases or prevented cases due to the new type of loose-housing should similarly not be of concern to other parties safeguarding the health and welfare of dairy cows.

Conclusion II: The replacement of Finnish Ayrshire cows with Finnish Black and Whites, on the other hand, *does* most likely pose a threat to EU objectives — Finnish Black and White cows have clearly higher risks for all diseases except ovarian disorders. The decreased welfare and increased costs attributable to the increased disease risk is probably not of large concern to the farmer (again, thanks to relatively low incidences and small herds). Nevertheless, because the number of Finnish Black and White cows is anticipated to increase considerably in the near future, the number of additional cases at country-level will be high. Finnish Ayrshire cows, shown to have higher incidences of ovarian disorders, worse fertility and lower milk yield than Finnish Black and Whites are likely also not an optimal cow according to EU objectives.

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A
Questionnaire in Finnish

Helsingin Yliopisto 21.1.2004

Tilan tuotanto-olosuhteet

◇ Tilan pihattomuoto — lämminpihatto ❑ kylmäpihatto ❑

◆ Kylmäpihatto-osa

◇ Päivällä kylmäpihatto-osassa pidettävät eläimet?

	kesällä	talvella
lypsylehmät	❑	❑
ummessa olevat	❑	❑
hiehot	❑	❑
vasikat	❑	❑

◇ Kylmäpihatto-osassa suoritettavat toimenpiteet

	kesällä	talvella
poikiminen	❑	❑
lypsy	❑	❑
siemennys	❑	❑

◆ Lämmin-osa

◇ Päivällä lämpimässä-osassa pidettävät eläimet?

	kesällä	talvella
lypsylehmät	❑	❑
ummessa olevat	❑	❑
hiehot	❑	❑
vasikat	❑	❑

◇ Lämpimässä-osassa suorittavat toimenpiteet

	kesällä	talvella
poikiminen	❑	❑
lypsy	❑	❑
siemennys	❑	❑

◇ Eläimet, jotka liikkuvat vapaasti (eivät ole kytkettynä) — lypsylehmät ❑ / ummessa olevat ❑ / hiehot ❑

◇ Laiduntaminen

	ei	paivällä	päivällä ja yöllä	laidunkausi 1996 ja 1997: 1996	1997
lypsylehmä	❑	❑	❑	______-______96	______-______97
ummessa olevat	❑	❑	❑	______-______96	______-______97
hiehot	❑	❑	❑	______-______96	______-______97
vasikat	❑	❑	❑	______-______96	______-______97

◆ Jaloitteluealue — ei ole ❑ / on ❑

◆ Milloin ?

◇ kesällä — ____ tuntia per päivä / vapaa pääsy ❑

◇ talvella — ____ tuntia per päivä / vapaa pääsy ❑

◇ Pohjamateriaali — betoni ❑ / maapohja ❑ / muu ____________

◆ Pihattorakenne

◇ Pihatto on — kombi ❑ / lyhytparsipihatto ❑ / makuuparsipihatto ❑ / vinokuivikepohja ❑ / kestokuivikepohjapihatto ❑ / osakuivikepohjopihatto ❑ / muu ________________________

- Seinät — suljettu rakennus ☐ / avoin rakennus ☐, moneltako sivulta_____
  - Verkkoseinä — ei ☐ / kyllä ☐
  - Kattomateriaali ______________________
- Sähkövalo — ei ☐ / kyllä ☐
  - Valonlähde — loisteputki / hehkulamppu
  - Lamppu palaa — talvella _____ / _____ tuntia / päivässä; kesällä _____ / _____ tuntia / päivässä
  - Arvioi lehmien vapaassa käytössä olevan alueen pinta-ala _______m^2
  - Pihaton käyttöönottovuosi — kuukausi________ vuosi ________
- Järjestelyt
  - Parsi

		määrä	pituus [cm]	leveys [cm]	parren korkeus lantakäytävästä [cm]
lypsylehmät	makuuparsi				
	ruokintaparsi				
hiehot					

- Parren lattiamateriaali — betoni ☐ / puu ☐ / kumimatto ☐ / parsipatja ☐ / kumimatto ja betoni yhdessä ☐ / joku muu, mikä ________________
- Ruokintapaikkojen lukumäärä lehmää kohti: — vähemmän kuin yksi per eläin ☐ / yksi per eläin ☐ / useampi kuin yksi per eläin ☐
- Ilmanvaihto — luonnollinen ☐ / koneellinen ☐
  - Luonnollinen
    - Säädeltävyys — ei ☐ / kyllä ☐
    - Rajoitetaanko ilmanvaihtoa kovien pakkasten aikaan — ei ☐ / kyllä ☐
      Miten ? ______________________
  - Koneellinen — ei ☐ / kyllä ☐
    - Venttiilien säätely — ei ☐ / automaattinen ☐ / mekaaninen ☐
- Merkkejä veden tiivistyminsestä — ei ☐ / kyllä ☐

	keväällä	syksyllä	talvella
ikkunoissa	☐	☐	☐
katossa	☐	☐	☐
seinissä	☐	☐	☐
________	☐	☐	☐

- Lannankäsittelymenetelmä — olkipatja ☐ / rakolattia ☐ / automaattinen lannanpoisto ☐ / lannankeräys traktorilla☐ / muu: ________________
  - Kuivikkeet — ei ☐ / hiekka ☐ / olki ☐ / kutteri ☐ / turve ☐ /

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- Poikiminen
  - ◇ Missä tapahtuu? poikimakarsinassa ❑ / laumassa ❑ / parsinavetassa ❑
  - ◇ Milloin emä palaa muun karjan joukkoon? ____ päivää poikimisen jälkeen
- Vasikat
  - ◇ Vasikoiden kasvatus tapahtuu aluksi yksittäiskarsinoissa ____ päivan ajan / ryhmäkarsinoissa ❑
  - ◇ Maidon ja juottorehun juotto vasikoille ämpäristä ❑ / aluksi tuttiämpäristä ❑ / juomaautomaatti ❑ / imetys ❑
  - ◇ Imevätkö vasikat toisiaan ? ei ❑ / harvoin ❑ / usein ❑
  - ◇ Imevätkö hiehot toisiaan ? ei ❑ / harvoin ❑ / usein ❑
  - ◆ Onko tilalla sairaskarsinaa ei ❑ / kyllä ❑ kylmässä tilassa ❑ / lämpimässä tilassa ❑
    - ◇ Montako karsinaa ? _____karsinaa
- Ovatko tilan tuotanto-olosuhteet muuttuneet 1996 alun jälkeen ?
  - ◇ Miten ? ____

  ____

Hoito ja ruokinta

- Lypsy
  - ◇ Lypsypaikka lypsyasema ❑ / vanhassa parsinavetassa ❑ / konttiasema ❑
  - ◇ Lypsykerrat ____kertaa päivässä
  - ◇ Vedinkasto ei ❑ / ongelmalehmille ❑ / kaikille lehmille ❑
  - ◇ Utareen esipuhdistus ei ❑ / kuiva ❑ / kostea ❑
  - ◆ Lypsypyyhkeet
    - ◇ Joka yksilölle oma ei ❑ / kyllä ❑ paperipyyhe ❑ / puuvillapyyhe ❑ / muu ❑
  - ◇ Lehmiä / lypsäjä ____
  - ◇ Lypsy-yksiköitä / lypsäjä ____
  - ◆ Lypsykone
    - ◇ Lypsykoneen ikä _______ vuotta
    - ◆ Vuosihuolto ei ❑ / kyllä ❑
      - ◇ Huollettu v.1996 ei ❑ / kyllä ❑
      - ◇ Huollettu v.1997 ei ❑ / kyllä ❑
    - ◇ Käytetäänkö kevytlypsintä ? ei ❑ / kyllä ❑
    - ◇ Lypsylisälaitteet irroitin ❑ / Duovac tai vastaava ❑ / muu, mikä ____________________
    - ◇ Kulkeeko maitoputki lehmän tason yläpuolella ei ❑ / kyllä ❑
    - ◇ Oletteko vaihtaneet viimeisen viiden vuoden aikana lypsykoneen perusosia ? ei ❑ / kyllä ❑ mitä____________________

- ◆ Lannankäsittely
  - ◆ Puhdistus
    - ◇ Parret ____ kertaa viikossa
    - ◇ Käytävät ____ kertaa viikossa
  - ◇ Lehmien puhtaus arvosteluasteikko 1-6 (6 = erittäin puhdas) ____
  - ◇ Makaileeko lehmiä käytävillä ei ❑ / kyllä ❑
- ◆ Hyönteisten ja tuhoeläinten torjunta
  - ◇ Hyönteistorjunta ei ❑ / kyllä ❑ / miten ____________________
  - ◇ Hyönteistorjunta laitumella ei ❑ / kyllä ❑ / miten ____________________
- ◇ Umpeenpanohoito antibiooteilla ei ❑ / ongelmalehmille ❑ / kaikille ❑
- ◇ Ammattisorkkahoito ei ❑ / kyllä, _____kertaa vuodessa / tarpeen mukaan ❑
- ◇ Sarvien poisto ei ❑ / kaikilta ❑ / ongelmalehmiltä ❑
- ◆ Poikiminen
  - ◇ Kuinka usein ongelmia poikimisissa (Vetoapua useamman kuin yhden ihmisen voimin) ________ kertaa vuonna 1996
- ◆ Siemennyskausi
  - ◇ Siemennykset aloitetaan 6 ❑ / 8 ❑ / 10 ❑ / ______ viikkoa poikimisen jälkeen
  - ◇ Tiineystarkastus ei ❑ / muutamille ❑ / kaikille ❑
    Miten progesteronitesti ❑ / eläinlääkäri ❑ / siementäjä ❑
  - ◇ Poikimiset tapahtuvat ympäri vuoden ❑ / poikimiset pyritään ajoittamaan___________ (vuodenaika)
  - ◇ Käytetäänkä omaa sonnia: ei ❑ / hiehoille ❑ / lehmille ❑
- ◆ Tavoitteet
  - ◇ Poikimaväli ____ päivää
  - ◇ Maitotuotos ____ kg /lehmä /vuosi
- ◇ Tilan tuotantoperiaate: perinteinen ❑ / Luomu ❑ / muu, mikä____________
- ◇ Onko sivutulolähteitä ? ei ❑ / metsä ❑ / kasvinviljelyä (muuhun kuin omaan käyttöön) ❑ / sianlihantuotantoa ❑ / lihakarjaa ❑ / muu sivuammatti ❑
- ◆ Kiimantarkkailu
  - ◇ Kiimantarkkailukalenteri tai tietokone ei ❑ / kyllä ❑
  - ◆ Kiimantarkkailuun kulutettu aika ________ tuntia / vrk
    - ◇ Milloin ? eläimiä lypsyyn koottaessa ❑ / lypsyn aikana ❑ / ruokinnan aikana ❑ / erillisen käynnin aikana ❑ / muulloin ____________________
  - ◆ Apuvälineen käyttö tarkkailussa ei ❑ / joskus ❑ / aina ❑
    - ◇ Tyyppi progesteronitesti ❑ / pedometri ❑
  - ◇ Milloin hiehot liitetään karjaan ____ päivää ennen poikimista / ____ päivää poikimisen jälkeen
- ◇ Käytetäänkö lihakarjan sonnia ei ❑ / kyllä ❑

◆ Tyytyväisyys pihaton työskenelyolohin talvella:
Arviointiasteikko 1 (epämiellyttävä) - 6 (erittäin hyvä)

◇ lämpötila: _____
◇ kosteus: _____
◇ valo: _____
◇ vetoisuus: _____
◇ ilman laatu: _____

◆ Ruokinta

◆ Poikimisen jälkeinen ruokinta

◇ Seosrehu ei ❑ / kyllä ❑

◆ Väkirehua

◇ Väkirehun tyyppi ja määrä korkeimman tuotoksen aikaan

tyyppi		*määrä korkeimman tuotoksen aikaan*
ohra	❑	_______kg
kaura	❑	_______kg
molempia	❑	_______kg
kaupallinen seos	❑	_______kg
muu, mikä	_______	_______kg

◇ Kuinka monta rehuyksiköä lehmä saa päivässa korkeimman tuotoksen aikana ? _______ ry/lehmä/päivä

◇ Ruokintakerrat ___kertaa päivässä / automaattiruokinta ❑

◆ Karkearehut

◇ Heinä ei ❑ / kyllä, ______ kg per päivä per lehmä / vapaasti ❑
◇ Säilörehu ei ❑ / kyllä, ______ kg per päivä per lehmä / vapaasti ❑
◇ Muuta ______________________________

◆ Säilörehu

◇ Esikuivattu ei ❑ / kyllä ❑ / molempia ❑
◇ Säilöntäaine ei ❑ / kyllä ❑ / mitä: _______________

◇ Valkuaisrehu rypsirouhe ❑ / soija ❑ / kaupallinen seos ❑ / muu, mikä: ____________________

◆ Tankkimaidon ureapitoisuus

	>35mg/100ml				<20mg/100ml			
1996	kerran	❑	useammin	❑	kerran	❑	useammin	❑
1997	kerran	❑	useammin	❑	kerran	❑	useammin	❑

◇ Saammeko lupanne kysyä meijeriltänne maidon rekisteröityä ureapitoisuutta ? ei ❑ / kyllä ❑

◆ Ummessa olevien ruokinta

◆ Väkirehut ___kertaa päivässä / ❑ automaattiruokinta

◆ Tunnutusruokinta ei ❑ / kyllä ❑
________vuorokautta ennen poikimista

◇ poikimista edeltävän

- ◆ Karkearehut (ummessa olevien)
  - ◇ Heinä ei ❑ / kyllä, ______ kg per päivä per lehmä / vapaasti ❑
  - ◇ Säilörehu ei ❑ / kyllä, ______ kg per päivä per lehmä / vapaasti ❑
  - ◇ Muuta ______________________________
- ◇ Hiehojen ryhmäjako samassa ryhmässä lypsylehmien kanssa ❑ / omana ryhmänään ❑
- ◆ Kalsiumruokinta
  - ◆ Rajoitettu ei ❑ / kyllä ❑
    - ◇ miten ____________________
- ◇ Muuta ummessa olo ajan ruokintaan liittyvää ______________________________
____

- ◆ Lisäaineruokinta
  - ◆ Vitamiineja
    - ◇ Lypsylehmille ei ❑ / kyllä ❑ / mitä: ______________
    - ◇ Ummessa oleville ei ❑ / kyllä ❑ / mitä: ______________
    - ◇ Hiehoille ei ❑ / kyllä ❑ / mitä: ______________
  - ◆ Kivennäisä
    - ◇ Lypsylehmille ei ❑ / kyllä ❑ / mitä: ______________
    - ◇ Ummessa oleville ei ❑ / kyllä ❑ / mitä: ______________
    - ◇ Hiehot ei ❑ / kyllä ❑ / mitä: ______________
  - ◇ Seleeniä ei ❑ / kyllä ❑
  - ◇ Propyleeniglykolia ei ❑ / kyllä ❑
  - ◇ muuta, mitä ______________________________
- ◆ Laidunkasvillisuus
  - ◇ Pääasiallinen kasvi Raiheinä ❑ / Timotei ❑ / Apila ❑ muu, mikä: ____________________
  - ◇ Maaperän tyyppi ______________________________
  - ◆ Lisäruokinta laitumella
    - ◇ Karkearehua lypsylehmille ❑ / ummessa oleville ❑ / hiehoille ❑
    - ◇ Kivennäistä lypsylehmille ❑ / ummessa oleville ❑ / hiehoille ❑
- ◆ Ovatko hoito - ja ruokintaolosuhteet muuttuneet 1996 alun jälkeen ?
  - ◇ Miten ? ____
____

Kommentteja

Kiitos

Christian Schnier, Teppo Heinola, Hannu Saloniemi ja Laura Kulkas

B

Questionnaire in Swedish

Helsingfors Universitet 21.1.2004

Produktionsmiljön

◇ Form av lösdrift — varm lösdrift ❑ / kall lösdrift ❑

◆ Kall hållning

◇ Vilka djur hålls i den kalla delen under dagen?

	sommar	vinter
mjölkkor	❑	❑
sinkor	❑	❑
kvigor	❑	❑
kalvar	❑	❑

◇ Arbete som utförs på den kalla sidan

kalvning	❑	❑
mjölkning	❑	❑
inseminering	❑	❑

◆ Varm hållning

◇ Vilka djur hålls i den varma delen under dagen?

	sommar	vinter
mjölkkor	❑	❑
sinkor	❑	❑
kvigor	❑	❑
kalvar	❑	❑

◇ Arbete som utförs på den varma sidan

kalvning	❑	❑
mjölkning	❑	❑
inseminering	❑	❑

◇ Vilka djur rör sig fritt (är inte fixerade)? — mjölkkor ❑ / sinkor ❑ / kvigor ❑

◇ Bete

	ingen bete	dagstid	dag og natt	*betesperiod 1996 och 1997* 1996	1997
mjölkkor	❑	❑	❑	____-____96	____-____97
sinkor	❑	❑	❑	____-____96	____-____97
kvigor	❑	❑	❑	____-____96	____-____97
kalvar	❑	❑	❑	____-____96	____-____97

◆ Rastgård — finns ❑ / finns ej ❑

◆ Används när?

◇ På sommaren — ________ timmar per dag / fritt ❑

◇ På vintern — ________ timmar per dag / fritt ❑

◇ Bottenmaterial — betong ❑ / jordbotten ❑ / annat ________________

◆ Lösdriftens konstruktion

◇ Lösdriften är en — kombi ❑ / fångbås ❑ / lösdrift med liggbås ❑ / lösdrift med lutande ströbädd ❑ / lösdrift med ströbädd ❑ / ströbädd med gjuten gång ❑ / annan lösdrift, vilken? ________________

- ◆ Väggar — stängd byggnad ❑ / öppen byggnad, öppen på _______ sidor
  - ◇ Nätvägg — nej ❑ / ja ❑
- ◇ Takmaterial ______________________
- ◆ El-belysning
  - ◇ Ljuskälla — ljusrör / gödlampa
  - ◇ Lampan brinner — på sommaren _______ / _______ timmar / dag; på vintern _______ / _______ timmar / dag
- ◇ Bedöm den golvareal som korna fritt kan använda — _______ m²
- ◇ Datum då lösdriften togs i bruk — månad_______ år ________

Inredning

◆ Bås

	antal	längd (cm)	bredd (cm)	båsets höjd från gödselgång (cm)
mjölkkor vilobås				
kvigor				

- ◇ Golvmaterial i båsen — betong ❑ / trä ❑ / gummimatta ❑ / båsmadrass ❑ / kombination av gummi och betong ❑ / annat, vad? ________________
- ◇ Antal utfodringsplatser per ko — färre än en per djur ❑ / en per djur ❑ / flera än en per djur ❑
- ◆ Ventilation — naturlig ❑ / maskinell ❑
  - ◆ Naturlig ventilation
    - ◇ Möjlighet att reglera — nej ❑ / ja ❑
    - ◇ Minskas ventilationen vid hård kyla ? — nej ❑ / ja ❑; hur ? ____________________________
  - ◆ Maskinell ventilation
    - ◇ reglering av ventilationen — nej ❑ / automatisk ❑ / mekanisk ❑
- ◇ Finns det tecken på vattenkondensation ? nej ❑ / ja ❑

	vår	höst	vinter
fönster	❑	❑	❑
tak	❑	❑	❑
väggar	❑	❑	❑
________	❑	❑	❑

- ◆ Utgödslingssystem
  - ◇ Typ — djupbädd ❑ / spaltgolv ❑ / automatisk utgödsling ❑ / utgödsling med traktor ❑ / annat, vad:_________________________
  - ◇ Strö — nej ❑ / sand ❑ / halm ❑ / kutterspån ❑ / torv ❑ / sågspån ❑ / annat, vad? _______________

- ◆ Kalvning
  - ◇ Var ? — i kalvningsbås ❑ / i flocken ❑ / i båsstall ❑
  - ◇ Kon kommer tillbaka till flocken — ____ dagar efter kalvningen
- ◆ Kalvarna
  - ◇ Hålls kalvarna till en början — i enskilda bås under _______dagar / i gruppboxar ❑
  - ◇ Utfodring av kalvarna sker med — ämbar ❑ / tuttämbar ❑ / automat ❑ / kalvarna diar kon ❑
  - ◇ Suger kalvarna på varandra? — nej ❑ / sällan ❑ / ofta ❑
  - ◇ Suger kvigorna på varandra? — nej ❑ / sällan ❑ / ofta ❑
- ◆ Finns det sjukbås på gården — nej ❑ / ja ❑ i de kalla utrymmena ❑ / i de varma utrymmena ❑
  - ◇ Hur många sjukbås finns det? — _______
- ◇ Har gårdens produktionsmiljö förändrats efter början på år 1996 ? Hur ?

  ____

Skötsel och Utfodring

- ◆ Mjölkning
  - ◇ Mjölkningsplats — mjölkningsstation ❑ / i det gamla båsstallet ❑
  - ◇ Mjölkningsgånger — ____ gånger per dag
  - ◇ Spendopp — nej ❑ / problemkor ❑ / alla kor ❑
  - ◇ Putsning av juver före mjölkning — nej ❑ / torr ❑ / våt ❑
  - ◆ Juverduk
    - ◇ Individuella dukar för varje ko — nej ❑ / ja ❑ pappersduk ❑ / bomullsduk / annan duk ❑
  - ◇ Antal kor / mjölkare — ______
  - ◇ Antal mjölkningsenheter / mjölkare — ______
  - ◆ Mjölkmaskin
    - ◇ Ålder — ____.år
    - ◆ Årlig service — nej ❑ / ja ❑
      - ◇ Service utförd år 1996 — nej ❑ / ja ❑
      - ◇ Service utförd år 1997 — nej ❑ / ja ❑
    - ◇ Används lättvikts organ — nej ❑ / ja ❑
    - ◇ Mjölkmaskinens tilläggsapparater — avtagare ❑ / Durovac eller motsvarande ❑ / annat, vad ?______________________
    - ◇ Löper mjölkslangen över kornas nivå — nej ❑ / ja ❑
    - ◇ Har mölkmaskinens basdelar bytts ut under de senaste fem åren? — nej ❑ / ja ❑ vilka ? ______________________

◆ Utgödsling
- ◆ Rengöring
  - ◇ Bås ____ ggr. per dag
  - ◇ Gångar ____ ggr. per dag
- ◇ Kornas renhet — bedömning från 1-6 (6 = mycket rena)._______.
- ◇ Ligger det kor i gångarna — nej ❑ / ja ❑

◆ Bekämpning av insekter
- ◇ Insektbekämpning i lösdriften — nej ❑ / ja ❑ / hur?___________________
- ◇ Insektbekämpning på bete — nej ❑ / ja ❑ / hur?___________________

◇ Antibiotikabehandling av sinkor — nej ❑ / problem kor ❑ / alla kor ❑

◇ Professionell vård av klövar — nej ❑ / ja, ____ gånger per år / vid behov ❑

◇ Avhorning — nej ❑ / problem kor ❑ / alla kor ❑

◆ Kalvning
- ◇ Hur ofta inträffar problemkalvningar? (Draghjälp med hjälp av mer än en person) _______ gånger under år 1996

◆ Inseminationsperiod
- ◇ Insemination inleds — 6 ❑ / 8 ❑ / 10 ❑ / ________ veckor efter kalvning
- ◆ Dräktighetskontroll — nej ❑ / endel kor ❑ / alla ❑
  - ◇ hur? — progesterontest ❑ / veterinär ❑ / inseminatör ❑
- ◇ Kalvningssäsong — hela året ❑ / kalvningarna koncenteras till (årstid)___________
- ◇ Används egen tjur? — nej ❑ / för kvigor ❑ / för kor ❑

◆ Mål
- ◇ Kalvningsintervall ____ dagar
- ◇ Mjölkproduktion ____ kg per ko per år

◇ Gårdens produktionsprincip — traditionell ❑ / naturenlig (luomu) ❑ / annan, vilken?___________________________

◇ Sidoinkomster — nej ❑ / skog ❑ / säd (ej för eget bruk) ❑ / svinköttsproduktion ❑ / köttboskap ❑ / annat ❑

◆ Brunstkontroll
- ◇ Brunstkalender eller datamaskin — nej ❑ / ja ❑
- ◆ Tid som används för brunstkontroll _______ minuter per dygn
  - ◇ När? — då djuren samlas för mjölkning ❑ / vid mjölkning ❑ vid utfodring ❑ / vid skilt tillfälle ❑ / övrig tid, när? ____________________
  - ◆ Hjälpmedel vid kontroll — nej ❑ / ibland ❑ / alltid ❑
    - ◇ Typ — progesterontest ❑ / pedometer❑

Helsingfors Universitet 21.1.2004

◇ När introduceras kvigor till flocken? _______ dagar före kalvning
_______.dagar efter kalvning

◇ Används tjur av köttras? nej ❑ / ja ❑

◇ Arbetsförhållandena i lösdriften på vintern:
Använd skalan 1-6 (1 mycket obehagliga, 6 mycket bra)

◇ Temperatur: _______

◇ Fuktighet: _______

◇ Ljus: _______

◇ Drag: _______

◇ Luftkvalitet: _______

Utfodring

◆ Utfodring efter kalvning
  ◇ Blandfoder nej ❑ / ja ❑

◆ Kraftfoder
  ◇ Kraftfodrets typ och mängd under högproduktion

typ		*mängd under högproduktion*
korn	❑	_______kg
havre	❑	_______kg
korn og havre	❑	_______kg
kommersiell blandning	❑	_______kg
annat, vad ?	_______	_______kg

◇ Hur många foderenheter (kraftfoder proteinfoder og grovfoder) får korna per dag då produktionen är som högst? _______FE per ko per dag

◇ Antal utfodringar (kraftfoder) _______ggr. per dag ❑ / Automatisk utfodring ❑.

◆ Grovfoder
  ◇ Hö nej ❑ / ja,_________ kg per dag per ko / fritt ❑
  ◇ Ensilage nej ❑ / ja,_________ kg per dag per ko / fritt ❑
  ◇ annat, vad? _________________________

◆ Ensilage
  ◇ Förtorkat nej ❑ / ja ❑ / både och ❑
  ◇ Ensileringsmedel nej ❑ / ja ❑, vad: _______________

◇ Proteinfoder rypskross ❑ / soja ❑ / komersiell blandning ❑ / annat, vad ? _______________

◆ Tankmjölkens ureahalt

	>35mg/100ml		<20mg/100ml	
1996	en gång ❑	flera ggr. ❑	en gång ❑	flera ggr. ❑
1997	en gång ❑	flera ggr. ❑	en gång ❑	flera ggr. ❑

◇ Godkänner Ni att vi frågar Ert mejeri om mjölkens registerade ureahalt? nej ❑ / ja ❑

- Utfodring av sinkor
  - ◇ Kraftfoder ________ggr. per dag / automatisk utfodring ❑
  - ◆ Special utfodring inför kalvning nej ❑ / ja ❑
    - ◇ När ? från ________ dagar före kalvning
    - ◇ Kraftfodermängd under dygnet innan kalvning _____ kg per dygn
  - ◆ Grovfoder för sinkor
    - ◇ Hö nej ❑ / ja,__________ kg per dag per ko / fritt ❑
    - ◇ Ensilage nej ❑ / ja,__________ kg per dag per ko / fritt ❑
    - ◇ Annat, vad? ________________________
  - ◇ Kvigorna hålls med resten av korna ❑ / i egen grupp ❑
  - ◆ Kalciumutfodring (sinkor)
    - ◇ Begränsad nej ❑ / ja ❑ , hur? ____________________
  - ◇ Annat som tas i beaktande vid utfodring av sinkor ________________________
- Tilläggs utfodring
  - ◆ Vitaminer
    - ◇ Mjölkkor nej ❑ / ja ❑ / vilka ?__________________
    - ◇ Sinkor nej ❑ / ja ❑ / vilka ?__________________
    - ◇ Kvigor nej ❑ / ja ❑ / vilka ?__________________
  - ◆ Mineraler
    - ◇ Mjölkkor nej ❑ / ja ❑ / vilka ?__________________
    - ◇ Sinkor nej ❑ / ja ❑ / vilka ?__________________
    - ◇ Kvigor nej ❑ / ja ❑ / vilka ?__________________
  - ◇ Selen nej ❑ / ja ❑
  - ◇ Propylenglycol nej ❑ / ja ❑
- Bete
  - ◇ Huvudsaklig betesväxt Rajgräs ❑ / Timotej ❑ / Klöver ❑ annan, vilken? ____________________
  - ◇ Markens typ ________________________
  - ◆ Tilläggsutfodring på bete
    - ◇ Grovfoder mjölkkor ❑ / sinkor ❑ / kvigor ❑
    - ◇ Mineraler mjölkkor ❑ / sinkor ❑ / kvigor ❑

◇ Har skötsel- och utfodringsrutinerna förändrats sen början på år 1996? Hur?
____

◇ ***Kommentarer***

Tack

Christian Schnier, Teppo Heinola, Hannu Saloniemi og Laura Kulkas