# Housing, Management and Health in Swedish Dairy Calves

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**Doctoral thesis**
**Swedish University of Agricultural Sciences**
**Skara 2004**

**Acta Universitatis Agriculturae Sueciae**
Veterinaria 168

ISSN 1401-6257
ISBN 91-576-6656-3

Tryck: SLU Service/Repro, Uppsala 2004

# Abstract

Lundborg, K. 2004. *Housing, management and health in Swedish dairy calves.*
Doctor's dissertation.
ISSN 1401-6257, ISBN 91-576-6656-3

This thesis discusses the results of an observational study conducted in dairy herds in the south-western Sweden and a questionnaire survey of dairy herds done throughout Sweden. In the observational study the health of 3 081 heifer calves in 122 dairy herds was monitored from birth until 90 days of age. Disease incidence was recorded by farmers and by project veterinarians. The calves' heart girth was measured at birth and at weaning. The average growth of the calves was 600 g per day. We investigated the effects of calf-level, herd-related and dam-related factors on growth and the incidence risk of infectious diseases. The total morbidity found was 23%; enteritis and respiratory disease were the most common diagnoses. The placing of calf pens along an outer wall, ingestion of first colostrum by suckling, receiving colostrum from a younger cow, being of Swedish Red and White breed (SRB) and birth during the summer were significantly associated with an increased risk for enteritis. A low ammonia concentration, draught, bovine viral diarrhoea virus infection in the herd, a poor capacity of the farmer to keep accurate records, being a cross-breed, housing in large group pens, and birth during the winter season, during the night, in a cubicle, a group calving pen or at pasture, as well as unsupervised calving, and factors related to the health of the dam were significantly associated with an increased risk of respiratory morbidity. Receiving colostrum from a young cow, absence of draught, being housed in a calf pen placed along an outer wall and being born during the night were found to be significantly associated with an increased risk of other infectious diseases. Growth was negatively affected by being of SRB breed, housing in large group pens, disease, difficult calving, first parity of the dam and retained placenta. The questionnaire was sent to 1 500 dairy farmers in Sweden and asked for routines from birth to first calving for replacement heifers. It identifies several areas in which advisory input is urgently needed, such as the colostrum routines, the heating of whole milk and the housing of calves and heifers.

*Key words:* ambient environment, calf growth rate, colostrum, dairy calf morbidity, diarrhoea, feeding, infectious diseases, parity, risk factors, respiratory disease

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"Arbete är det mest fantastiska som finns här i världen,
så vi bör alltid spara en del till morgondagen."
*Don Herrold*

***To my family and to my friends,
both two- and four-legged***

# Contents

# Appendix

## Papers I–IV

The present thesis is based on the following papers, which will be referred to by their Roman numerals:

**I.** Svensson, C., Lundborg, K., Emanuelson, U., & Olsson S.-O. 2003. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Preventive Veterinary Medicine 58*, 179–197.

**II.** Lundborg, G.K., Svensson, E.C., & Oltenacu, P.A. Herd-level risk factors for infectious diseases in Swedish dairy calves aged 0–90 days. (Submitted manuscript)

**III.** Lundborg, G.K., Oltenacu, P.A., Maizon, D.O., Svensson, E.C., & Liberg, P.G.A. 2003. Dam-related effects on heart girth at birth, morbidity and growth rate from birth to 90 days of age in Swedish dairy calves. *Preventive Veterinary Medicine 60*, 175–190.

**IV.** Pettersson, K., Svensson, C., & Liberg, P. 2001. Housing, feeding and management of calves and replacement heifers in Swedish dairy herds. *Acta Veterinaria Scandinavica 42*, 465–478.

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# Abbreviations

| | |
|---|---|
| AI | artificial insemination |
| BRSV | bovine respiratory syncytial virus |
| BVDV | bovine viral diarrhoea virus |
| IgG | immunoglobulin G |
| OR | odds ratio |
| ppm | parts per million |
| RSV | respiratory syncytial virus |
| SD | standard deviation |
| SLB | Swedish Holstein |
| SRB | Swedish Red and White Breed |

# Introduction

## General background

Until the mid-20th century developments in Swedish agriculture were very slow. The structural rationalisations introduced in the 1950s, however, brought dramatic change and continued to do so until the 1970s (Ekesbo, 1973). The traditions of housing and management were most affected. Many farmers began to specialise in only one production area. The production units became bigger and the number of animals per farm increased. According to records from Sweden's National Central Bureau of Statistics, in 1950 there were 1 654 400 cows (both dairy and beef) in Sweden. By 1971 this number had decreased to 757 700. In 1971 the average number of cows per farm was 7.9. In 2002 there were only 417 100 dairy cows in Sweden. The average number of dairy cows per farm was, however, 37.0. The changes in animal housing and management routines were mostly triggered by economic interests and had some negative effects on the health of the animals. An intensive research on the housing and management of cows was therefore initiated in Sweden and in the front rank by Ekesbo (*e.g.* 1966, 1973, 1974, 1988). Other Swedish researchers followed, including Ekesbo & Vilson (1978), Bendixen *et al.* (1986), Hultgren & Bergsten (2001) and Manske, Hultgren & Bergsten (2002). The research efforts during the last decades have resulted in great improvements in the ambient environment of the dairy cows. Corresponding research and improvements in favour of their calves have, however, not been seen. The knowledge of the calves' environmental and management needs is therefore still poor compared with knowledge regarding the requirements of the adult cow. Calves have often been overlooked and have rarely been given an optimal environment or management. Increased knowledge is therefore of utmost importance if we want to optimise their rearing conditions.

### *Historical aspects of housing and management of Swedish dairy calves*

During the late 19th and early 20th centuries Swedish textbooks on animal production science recommended single pens as the optimal housing system for the pre-weaned calf and group pens or tying up for weaned calves. It was said that the young calf should have a dry, clean and draught-free pen (Blomqvist, 1895; Lampe, Schwartz & Seyfert, 1911; Linman, 1920). There were no further specifications in these books on how the pens should be constructed. Blomqvist (1895) stated that calves should be fed small amounts of milk at least five times a day and that the best way of feeding them was to let them stay with their mothers. Dilution of the milk with hot water was recommended for calves that seemed to have problems digesting the milk. In contrast to Blomqvist (1895), Lampe, Schwartz & Seyfert (1911) and Linman (1920) recommended that calves should be separated from their mother immediately after birth to protect them from the harmful consequences of weaning later on. The importance of giving the calf colostrum was emphasised because it was believed that colostrum had a purgative ability. After the colostrum period the calves were to be given 6–10 L of milk per day, divided into three meals. They were also to be fed hay of good quality and oats, barley or chopped root vegetables (Blomqvist, 1895; Lampe, Schwartz & Seyfert, 1911; Linman, 1920).

In the early 1960s pens with slatted floors for weaned calves were introduced in Sweden, which led to increased health problems with diarrhoea and respiratory disease (Ekesbo, 1973). After a breakthrough was achieved in artificial insemination (AI) the life span of dairy cows was shortened and more replacement animals were needed. This meant that the number of calves per farm increased, which often made farmers increase the number of calves per pen without correspondingly increasing the area of the pen (Ekesbo, 2003). Likewise, in the 1950s fans for ventilation and liquid manure systems were introduced. The introduction of liquid manure meant that the amount of straw had to be strongly reduced; often calves were kept directly on the slatted floor in single pens without any straw (Ekesbo, 1973; 2003). The reduced amount of straw caused not only health problems in the calves but also, symptoms of stress such as abnormal licking of walls or playing with the tongue (Ekesbo, 1978).

### *Modern housing and management of dairy calves*

Many of the recommendations in the old textbooks regarding the care of calves are still being followed and are of obvious importance for the practical animal management of today. Not least, many of the old hygienic recommendations are relevant also in modern animal production. Developments in medical science, including the development of modern antibiotics, have sometimes reduced awareness of the impact of preventive health care. Today, when the number of animals per caretaker is highly increased compared with only 10–15 years ago, it may be tempting to reduce the daily work per animal, for instance by reducing the hours spent on providing a hygienic environment for the calves. Providing calves with a clean and dry ambient environment remains as important as ever.

The housing of calves in Sweden has been resting on long traditions. The single pen is still the most commonly used housing system for young calves (Bernes, Martinsson & Pettersson, 1986; Norrman, 1990; Stenebo, 1995). The single pen system usually consists of a linked, ready-made system in which the floors of the pens are elevated above the stable floor. According to the Swedish animal welfare legislation of 1998, single pens for calves weighing less than 60 kg should measure at least 1.2 x 1.0 $m^2$ (the minimum space for calves between 60 kg and 90 kg is 1.4 x 1.1 $m^2$) and have solid walls up to a height of 80 cm, above which calves in adjoining pens should be able to have social contact with each other. Calves can reach feeding buckets through the front wall of the pens. Water may be given in buckets or through nipple drinkers. Roughage is often provided in small hayracks on top of the pen wall (Figure 1).

Figure 1. Single pen. (*Photo: Catarina Svensson*)

The second most common housing system for young calves is the small group pen (Bernes, Martinsson & Pettersson, 1986; Norrman, 1990; Stenebo, 1995). The small group pen may have a variety of appearances and usually houses up to six calves. According to the current Swedish animal welfare legislation, each calf weighing less than 60 kg should have a total area of at least 1.5 $m^2$, of which 1.0 $m^2$ must be a resting area (for calves weighing between 60 kg and 90 kg, the corresponding areas are 1.7 $m^2$ and 1.2 $m^2$, respectively). Milk is usually fed in buckets and water is usually provided by nipple drinkers (Figure 2).

Figure 2. Small group pen. (*Photo: Catarina Svensson*)

Some of the housing and management recommendations traditionally put into practice in dairy production in Sweden are now being questioned. We now have more knowledge about risk factors for different diseases and for retarded growth, and also, about the animals' need for natural and social behaviour. This has for instance led to a discussion about the use of single pens for young calves and of the limited possibilities this housing system offers for their patterns of behaviour (Dellmeier, Friend & Gbur, 1985; Webster *et al.*, 1985; Veissier *et al.*, 1994; Jensen, 1999; Chua *et al.*, 2002). At the same time the recent increase in herd size has led to the development of new housing systems and technical solutions for feeding systems, which emphasises the need for modified recommendations. A new housing system which has been used in Sweden since the late 1980s is the large group pen with an automatic milk feeding system. There are two major types of automatic milk feeding systems, one that enables free access to the milk and the other that regulates the amount of milk per meal and day via a transponder and a computerised system. In both systems the calves usually get the milk by sucking an artificial teat. If the milk supply is restricted, the artificial teat is usually placed within a feeding stall so that the possibility for other calves to push away the calf sucking on the teat is limited. According to the manufacturers of this system, the automatic milk feeder is able to serve up to 25 calves (Figure 3).

Figure 3. Large group pen with automatic milk feeding system. (*Photo: Karin Lundborg*)

The new awareness of natural behaviour and environmental and management risk factors for disease has also led to new recommendations for the management of calving and the colostrum period. The use of calving pens, considered to promote the welfare of both the cow and the calf, is an example of the implementation of such new knowledge (Stott *et al.*, 1979a; Lidfors, 1996; Krohn, Foldager & Mogensen, 1999). The importance of the quality and quantity of colostrum given to the newborn calf has been thoroughly investigated during the last few decades and new recommendations have been made (Shearer *et al.*, 1992; Robison, Stott & DeNise, 1988; DeNise, Robison & Stott, 1989; Wittum & Perino, 1995; Donovan *et al.*, 1998b; Liberg & Carlsson, 1998; Liberg, 2000). In a standard guide to calf care, *The Calf* by Roy (1990), the recommendation is that the calf should stay with its mother during the first few days to receive proper amounts of colostrum. The importance for the calf of receiving the colostrum within the first 4 hours after birth is emphasised, as is the importance of the quality of the colostrum.

The association between housing and health during the rearing period has been investigated by several authors (Goodger & Theodore, 1986; Curtis *et al.*, 1988; Perez *et al.*, 1990; Maatje *et al.*, 1993; Olsson *et al.*, 1993; Kung *et al.*, 1997; Virtala *et al.*, 1999). Management-related factors have also been found to be correlated to calf health (Stott *et al.*, 1979a; Devery-Pocius & Larson, 1983; Eigenmann *et al.*, 1983; Petrie, 1984; Michanek & Ventorp, 1989; Besser, Gay & Pritchett, 1991; Sivula *et al.*, 1996b; van der Fels-Klerx, Horst & Dijkhuizen, 2000) as well as to the calves' growth (Sivula *et al.*, 1996b; Flower & Weary, 2001).

## Calf diseases

Infectious diseases are the most important health problems in young calves, enteritis and respiratory syndromes being the most common diseases (Simensen & Norheim, 1983a; Waltner-Toews *et al.*, 1986; Correa *et al.*, 1988; Perez *et al.*, 1990; Olsson *et al.*, 1993; Sivula *et al.*, 1996a; Virtala *et al.*, 1996a). Among common infectious diseases in young calves are also omphalophlebitis and arthritis. The infectious diseases will be discussed in greater detail below. Non-infectious health problems in young calves include digestive disorders, such as bloat and ruminal indigestion, and deficiency diseases, such as muscle degeneration caused by selenium deficiency. Risk factors for non-infectious diseases are rarely to be found in housing or management, but will rather be found within *e.g.* the area of feeding. Traumatic injuries, such as broken legs, are sometimes seen in young calves (Radostits *et al.*, 1999). They could of course be traced back to the housing system, but they are more likely due to single bad technical solutions than to the housing system as a whole.

### *Enteritis*

Enteritis is the most common disease in calves less than 1 month of age (Waltner-Toews *et al.*, 1986; Gardner *et al.*, 1990; Perez *et al.*, 1990; Virtala *et al.*, 1996a; Wells, Garber & Hill, 1996; Radostits *et al.*, 1999). Diarrhoea may be functional, due to dietary factors or caused by infections with viruses, bacteria or parasitic agents. The clinical outcome of an infectious diarrhoea is strongly influenced by environmental and management factors, which means that the disease is considered to be multi-factorial (Bruning-Fann & Kaneene, 1992). It is well known that the colostrum routines are of great importance for the level of immunoglobulin G (IgG) in the calves' blood (Devery-Pocius & Larson, 1983; Odde, 1988; Besser, Gay & Pritchett, 1991; Shearer *et al.*, 1992; Michanek & Ventorp, 1993; Rajala & Castrén, 1995; Liberg & Carlsson, 1998; Liberg, 2000) and therefore also for the number of clinical cases of diarrhoea in the herd (Wittum & Perino, 1995). The level of diarrhoea in a herd is also associated with the hygienic routines (Perez *et al.*, 1990). Enteritis is clinically recognised by faeces with a looser consistency than normal. The colour and the smell of the faeces are often affected. Diseased animals may have fever, and may be depressed owing to dehydration and possibly acidosis (Radostits *et al.*, 1999). It is usually not possible to differentiate between different infectious agents causing diarrhoea through clinical findings. Laboratory diagnosis is needed (Radostits *et al.*, 1999). Rotavirus, coronavirus, *Escherichia coli K99+* and *Cryptosporidium parvum* have been reported to be the most important pathogens in neonatal enteritis (see, *e.g.*, Snodgrass *et al.*, 1986; Waltner-Toews, Martin & Meek, 1986a). Other pathogens causing enteritis in calves during their first 3 months of life are *Eimeria* spp., bovine viral diarrhoea virus (BVDV), *Salmonella* spp., *Campylobacter* spp. and *Clostridium* spp. (Tzipori, 1981; Radostits et al., 1999).

***Rotavirus*** is a worldwide, major cause of diarrhoea in all young, intensively reared animals (Fenner *et al.*, 1987) as well as in human children (Saif & Theil, 1990; Glass *et al.*, 1996). In several studies it has been found to be the most commonly detected agent among young calves with enteritis (Acres, Saunders & Radostits, 1977; Snodgrass *et al.*, 1986; Reynolds *et al.*, 1986). In a Swedish study by de Verdier Klingenberg & Svensson (1998) group A rotavirus was found in faeces of 43.8% of calves with diarrhoea. Björkman *et al.* (2004) found rotavirus in 23% of cases. Rotavirus usually affects calves between 1 and 8 weeks of age and the enteritis can vary from mild and subclinical to lethal (de Leeuw *et al.*, 1980). The colour of the faeces of infected calves is usually white to yellowish. The rotavirus infects the cells of the top of the villi in the small intestine and causes a reduction of the absorptive surface of the intestine, which leads to accumulation of fluid in the intestinal lumen and consequently to diarrhoea. The infection of the cells in the villi will also cause a reduced level of lactase, leaving undigested lactose to promote bacterial growth, and an increase in the osmotic effect (Fenner *et al.*, 1987; Saif & Theil, 1990). As the infection progresses the absorptive cells are replaced by immature cells. These cells are relatively resistant to the viral infection so the infection is often self-limiting unless dehydration is too severe. The rate of recovery is often rapid since the crypt cells are not damaged (Fenner *et al.*, 1987). Rotavirus is excreted in large numbers in the faeces of infected animals. The virus is very resistant and can survive in the faeces for several months, which means that the pen could be the source of infection of younger calves if not properly cleaned between animals (Saif & Theil, 1990).

The ***bovine coronavirus*** is another worldwide cause of enteritis in young calves and is most commonly seen in calves at about 1 week of age. The pathogenesis of the enteritis caused by the bovine coronavirus is similar to that caused by rotavirus although the diarrhoea is generally less severe (Fenner *et al.*, 1987). The clinical symptoms include watery, yellowish faeces and lack of appetite (Lu, Yao & Eichhorn, 1991).

***Escherichia coli K99+*** may cause diarrhoea in calves younger than 3 weeks of age, most commonly during the first 10 days (Morin *et al.*, 1978) as a primary or secondary pathogen. *Escherichia coli K99+* is part of the normal intestinal bacterial flora and causes disease only when its numbers are highly increased. The number of bacteria may reach high numbers for several reasons, such as improper colostrum routines, poor feeding routines, excessive stress, or infections with other pathogens (Wray & Thomlinson, 1975). The severity of the disease may vary and the morbidity within different herds may range from 30% to 75% and the case fatality, from 10% to 50% (Radostits *et al.*, 1999). *Escherichia coli K99+* produces enterotoxins which cause an excessive amount of fluid to be produced in the intestines, resulting in diarrhoea and dehydration. The colour of the faeces of affected calves is usually yellow to grey-white, and the faeces often have a very bad smell (Carter & Chengappa, 1991).

***Cryptosporidium parvum*** is an intracellular protozoan parasite belonging to the group of coccidiae. It may cause enteritis in mammals including humans (Dubey, Speer & Fayer, 1990; Long, 1990). In two Swedish studies *C. parvum* was found in the faeces of 19% and 11%, respectively, of the diarrhoeic calves (de Verdier Klingenberg & Svensson, 1998; Björkman *et al.*, 2004). In the UK *C. parvum* has been considered the second most common agent in neonatal diarrhoea in calves (Reynolds *et al.*, 1986). Calves suffering from cryptosporidiosis usually recover spontaneously within 1–2 weeks unless concomitant infections with other enteropathogens occur and aggravate the clinical signs (O'Donoghue, 1995). In a Danish study *C. parvum* was found mixed with other enteropathogens in the faeces of diseased calves in 45% of cases (Krogh & Henriksen, 1985). In a similar study from Spain 64.3% of calves aged 1–7 days and infected with *C. parvum* also had a concurrent infection while none of the infected calves aged 22–30 days had a mixed infection (de la Fuente *et al.*, 1999). The calves become infected when they ingest microscopic oocysts that are excreted in the faeces of infected animals (Urquhart *et al.*, 1991). Especially during the first 2 weeks after the infection large numbers of oocysts are shed in the faeces (Uga *et al.*, 2000). The parasites cause severe atrophy of the intestinal villi, which leads to malabsorption (Urquhart *et al.*, 1991).

***Eimeria bovis*** and ***E. zuernii*** also are intracellular protozoan parasites belonging to the group of coccidiae, and have a worldwide distribution (Urquhart *et al.*, 1991). The infection route is faecal-oral and the parasites infect the crypt cells in the large intestine and cause diarrhoea, which often is bloody (Hammond, Davis & Bowman, 1944; Stockdale, 1977; Taylor & Catchpole, 1994). The infection is aggravated by stress, such as a very cold or hot climate (Niilo, 1970; Urquhart *et al.*, 1991). *Eimeria* coccidiosis is most commonly seen in calves between 3 weeks and 6 months of age (Holliman, 2000).

Diarrhoea caused by ***bovine viral diarrhoea virus*** (BVDV) may, unlike that caused by most other viruses, occur at any age. Calves infected in utero may develop a special condition, mucosal disease characterised by chronic fever, anorexia, profuse, watery diarrhoea, nasal discharge, stomatitis and sometimes blindness (Done *et al.*, 1980; Fenner *et al.*, 1987). In cattle infected postnatally the course of the infection may vary from subclinical to explosive diarrhoea with fever and perhaps nasal and ocular discharge (Pellerin *et al.*, 1994). The infection causes an immunosuppression in the infected animals, which may lead to opportunistic infections with other intestinal or respiratory pathogens (Baker, 1987; Elvander *et al.*, 1998; de Verdier Klingenberg, 2000) and an increased mortality rate in the herd (Ersbøll, Rugbjerg & Stryhn, 2001).

The most common species of ***Salmonella*** infecting calves are *Salmonella dublin* and *S. typhimurium*. Fortunately, however, *Salmonella* spp. are uncommon in Swedish dairy herds as a result of many years of intensive control measures

(Wahlström, 2001). *Salmonella* usually affects calves between 2 and 6 weeks of age. The pathogen can be introduced into a herd via infected feed, water, pastures, cattle or humans, or via birds or rats. The calves are almost always infected orally. The symptoms in diseased calves are usually fever and bloody diarrhoea (Carter & Chengappa, 1991). According to the Swedish law regarding epizootic diseases, the laboratory has to report a positive diagnosis. In Sweden veterinarians and farmers are advised against using antibiotics for treating salmonellosis because of the risk of the bacteria developing resistance (Sternberg & Boqvist, 2003).

***Campylobacter coli*** and ***C. jejuni*** can be found as commensals in the intestines of healthy calves and cattle (Grau, 1988; Carter & Chengappa, 1991). The role of *C. jejuni* and *C. coli* as primary pathogens in calves is uncertain. Both agents have been shown to cause a mild to moderate mucoid enteritis with or without fever if inoculated experimentally (Al-Mashat & Taylor, 1980; Warner & Bryner, 1984). The findings at necropsy after an infection with *C. jejuni* may range from a diffuse catarrhal to a severe haemorrhagic enteritis in the jejunum and ileum. The clinical symptoms may vary from only a mild depression with faeces that is softer than normal, and no fever, to dysentery and high fever (Al-Mashat & Taylor, 1980).

The calf enterotoxaemia caused by ***Clostridium perfringens*** type B and C usually occurs in calves younger than 10 days of age. The clinical symptoms include severe diarrhoea, dysentery and acute abdominal pain. In very acute cases death may occur within a few hours, while in less severe cases recovery is very slow (Radostits *et al.*, 1999). *Clostridium perfringens* type A forms a part of the normal flora in many healthy animals and its role in the pathogenesis of enteritis is therefore uncertain. There are, however, reports of disease outbreaks in lambs, sheep, foals, calves and adult cattle from different parts of the world where *C. perfringens* type A was isolated in large numbers (Radostits *et al.*, 1999). *Clostridium perfringens* type A produces an alpha toxin which has haemolytic effects leading to haemorrhagic diarrhoea (Carter & Chengappa, 1991; Rood & Cole, 1991). Differential diagnoses of the haemorrhagic enteritis seen in calves are chronic copper poisoning, leptospirosis or infection with *C. perfringens* type B and C (Radostits *et al.*, 1999).

Pathogens are not an element of all cases of diarrhoea in young calves. Diarrhoea could also be related to the feed and feeding routines. One example of this is fermentative diarrhoea which occurs in calves usually at 3–4 weeks of age during the introduction of concentrates. If the calves receive excessive amounts of concentrates before they consume proper amounts of roughage, their ruminal micro-organisms will not be sufficiently developed to process the carbohydrates and proteins in the concentrate. The micro-organisms will convert the carbohydrates that pass into the intestines to organic acids. The proteins will cause an increase in the number of micro-organisms such as *E. coli* in the intestines. The organic acids and the toxins from the bacteria will cause diarrhoea. Poor feed and a poor feeding hygiene may also be an indirect cause of diarrhoea. For instance, the milk concentrate that is not properly stored could be an excellent substrate for bacteria and fungi (Roy, 1990; Radostits *et al.*, 1999).

*Respiratory disease*

The most common form of respiratory disease affecting young calves is enzootic pneumonia (Ames, 1997; Radostits *et al.*, 1999). Similarly to enteritis, pneumonia is considered to be a multi-factorial disease with causative agents, calf factors and environmental factors as components (Kiorpes, Dubielzig & Beck, 1988; Ames, 1997). The most common agents found in association with calf pneumonia are viruses such as bovine respiratory syncytial virus (BRSV), para-influenza-3 virus, bovine adenovirus and coronavirus; however, secondary bacterial infections with *Pasteurella multocida*, *Mannheimia haemolytica*, *Haemophilus somnus*, *Arcanobacterium pyogenes* or *Staphylococcus aureus* are not uncommon. Several bacteria may be found in the same diseased animal (Radostits *et al.*, 1999). *Mycoplasma* spp. could also be found as primary or secondary agents (Bitsch, Friis & Krogh, 1976; Kiorpes, Dubielzig & Beck, 1988; van Doenkersgoed *et al.*, 1993; Virtala *et al.*, 1996; Radostits *et al.*, 1999). The major bacterial pathogens involved in the enzootic pneumonia complex are all present as commensals in clinically normal cattle. Increased stress or viral infections can lead to their proliferation and increased virulence. In younger calves the source of infection is most often older cattle which via direct contact or aerosol droplets infect the younger calves that have not yet established a resident upper respiratory microflora of their own (Kiorpes, Dubielzig & Beck, 1988; Mosier, 1997).

Enzootic pneumonia usually affects calves between 1 and 6 months of age (Kiorpes, Dubielzig & Beck, 1988; Radostits *et al.*, 1999). Typical symptoms are fever (40–40.5$^{o}$C), at least initially, nasal discharge (which is transparent at first and later on becomes purulent if the calf suffers a secondary bacterial infection), coughing, and increased respiratory sounds at lung auscultation. If a secondary bacterial infection sets in the symptoms generally aggravate and the fever may increase to 41–41.5$^{o}$C. An aetiological diagnosis can be made from serological examinations, virus examinations from nasal discharge or by autopsy. If a bacterial infection has set in it is recommended that the calf should be treated with antibiotics (Kiorpes, Dubielzig & Beck, 1988; Radostits *et al.*, 1999).

The ***bovine respiratory syncytial virus*** (BRSV) is closely related to the human respiratory syncytial virus (RSV) (Baker, Ellis & Clark, 1997; Larsen, 2000), which has been associated with acute epidemics of respiratory disease in young children in the autumn and winter periods (Kiorpes, Dubielzig & Beck, 1988). Likewise, in cattle the virus has been found to be a worldwide cause of a number of epidemics of acute respiratory syndrome (Verhoeff & van Nieuwstadt, 1984; Baker, Ellis & Clark, 1997). Similar to the human RSV, the bovine virus has seasonality, with a peak occurrence in autumn and winter (Baker & Frey, 1985). The virus is suspected to be spread directly from infected animals, by transmission of humans or by airborne transmission (van der Pohl *et al.*, 1993; Elvander, 1996). The BRSV causes mild to severe respiratory tract disease, with complete loss of the ciliated epithelium in the respiratory tract within 8–10 days after infection (Baker, Ellis & Clark, 1997; Elvander *et al.*, 1998). This compromises the pulmonary clearance and makes the calf more susceptible to secondary bacterial infections. In general in newly infected herds the morbidity will be high, but the mortality low. A typical finding at autopsy is the presence of large syncytial cells in the lungs (Fenner *et al.*, 1987; Kiorpes, Dubielzig & Beck, 1988; Baker, Ellis & Clark, 1997).

***Para-influenza-3 virus*** is a ubiquitous agent occurring worldwide (Kapil & Basaraba, 1997). The virus causes a mild respiratory disease although some animals may develop an interstitial pneumonia. In uncomplicated cases the disease will have a clinical course of 3–4 days, usually with a complete recovery (Fenner *et al.*, 1987; Kiorpes, Dubielzig & Beck, 1988). The para-influenza-3 virus infects the bronchoalveolar macrophages and can therefore have an immunosuppressive effect, facilitating a pulmonary bacterial colonisation (Adair *et al.*, 1999).

The bovine adenovirus causes an acute, mild or subclinical respiratory disease that is usually restricted to the upper respiratory tract but may also comprise bronchopneumonia. It has been found to be a single pathological agent mainly in very young, colostrum-deprived or environmentally stressed calves (Kiorpes, Dubielzig & Beck, 1988).

***Pasteurella multocida*** and ***Mannheimia haemolytica*** are the most and second most common bacterial pathogens of respiratory disease in calves (Mosier, 1997). In a Swedish study from 1997–2000 *P. multocida* and *M. haemolytica* were the most common bacterial findings in calves with respiratory disease (Bengtsson & Viring, 2000). In general *P. multocida* is considered to be less pathogenic than *M. haemolytica* and to require more organisms to initiate an infection (Ames *et al.*, 1985). Both *M. haemolytica* and *P. multocida* are normal inhabitants of the bovine nasopharynx and under conditions of stress, such as during a concurrent viral infection, they proliferate and colonise the lower lung (Kiorpes, Dubielzig & Beck, 1988).

***Haemophilus somnus*** is present in both the upper respiratory tract and the urogenital tract of healthy cattle. This means that an animal, besides the regular routes of infection, can be infected by infected urine via aerosol (Corbeil *et al.*, 1986). *Haemophilus somnus* has been shown to be associated with a subacute to chronic bronchopneumonia (Mosier, 1997). In a Danish study *H. somnus* was common in pneumonic calves (Tegtmeier *et al.*, 1996). By contrast, none of the calves in Sweden with respiratory disease studied by Bengtsson & Viring (2000) was shown to be infected with *H. somnus*.

***Arcanobacterium pyogenes*** and ***Staphylococcus aureus*** are common commensals on the mucous membranes of the nasopharynx of cattle. They can cause disease when the calf's immune system is depressed, for instance owing to another infection (Carter & Chengappa, 1991). *Arcanobacterium pyogenes* rarely has a role in acute pneumonia but is quite often found as an opportunist bacterium in chronic pneumonia (Mosier, 1997). The spread to the lungs can be hematogeneous.

***Mycoplasma*** spp. have been isolated from calves with enzootic pneumonia, although their role as a single agent in clinical pneumonia is unclear (Ames, 1997; Kiorpes, Dubielzig & Beck, 1988). *Mycoplasma* spp. in combination with bacterial infections are associated with serious disease and have an immunosuppressive potential (Mosier, 1997). *Mycoplasma bovis* is the most common and the most pathogenic of the *Mycoplasma* spp. Different *Mycoplasma* spp. may be found in the same animal (Mosier, 1997).

### *Other infectious diseases*

***Infections in the umbilicus*** occur soon after birth and can result in omphalitis (inflammation of the external umbilicus) or omphalophlebitis (inflammation of the umbilical veins) (Radostits *et al.*, 1999). In a study from the USA the median age of umbilically infected calves was reported to be 1 week (Virtala *et al.*, 1996a). The bacterial flora involved in umbilical infections is usually mixed and may include *A. pyogenes*, *E. coli*, *Proteus* spp. and *Staphylococcus* spp. Through bacteremia the infection can be spread to joints, meninges and other internal organs, where at necropsy it has been found to have formed abscesses (Radostits *et al.*, 1999). Omphalitis usually occurs 2–5 days after birth and the typical picture is a moderately depressed calf with an enlarged umbilicus which is painful on palpation. Calves affected by omphalophlebitis are usually older (1–3 months) and their umbilicus may or may not be swollen. The calves are often severely depressed because of toxaemia. Treatment with antibiotics is rarely successful (Radostits *et al.*, 1999).

***Infectious arthritis***, which often is secondary to an umbilical infection, is most often found in the tarsal, knee and carpal joints. It usually affects calves during the first month of life. The most frequently found micro-organisms are *A. pyogenes*, *Fusobacterium necrophorum* and *Staphylococcus* spp. (Kallo, Abdul-Ghani, Khalid, 1997; Radostits *et al.*, 1999). Typical symptoms are one or more warm and swollen joints in a more or less lame calf, with fever. It is important to treat the infection with antibiotics as soon as possible to avoid irreversible damage to the joints (Fraser *et al.*, 1986).

***Abscesses in the cheek area*** caused by *F. necrophorum* can be found in calves about 2 weeks old. The pathogen probably infects the calf through lesions, which could be due to *e.g.* viral infections, in the mucous membranes of the mouth. Bad hygiene in the ambient environment is a known risk factor. The symptoms are fever, yellow-white necrosis on the tongue and in the pharynx, and salivation. Affected animals can also develop pneumonia. The infection may be treated with penicillin (Carter & Chengappa, 1991). *Fusobacterium necrophorum* could also be found as the pathogen in liver abscesses. The pathogen is probably spread from the primary lesion to the liver via the blood. Animals suffering from liver abscesses rarely show symptoms but their growth is affected (Radostits *et al.*, 1999).

## Economic aspects

The cost of raising replacement heifers is one of the most important components of the total milk-production economy (Annexstad, 1986; Heinrichs, 1993). From an economic point of view, when longevity and total life production are taken into account, the optimal age at first calving has been calculated to be 20.5–25.0 months (Gill & Allaire, 1976; Hartwig & Kilmer, 1984; Lin *et al.*, 1988; Hoffman

& Funk, 1992; Heinrichs, 1993; Mourits *et al.*, 2000). Infectious diseases during the calves' first 90 days of life are associated with a lowered possibility of entering the milk herd as a lactating cow, a higher age at first calving and a lower degree of survival (Britney *et al.*, 1984; Waltner-Toews, Martin & Meek, 1986c; Correa *et al.*, 1988; Curtis, White & Erb, 1989; Empel *et al.*, 1993; Warnick, Erb & White, 1995, 1997). Infectious diseases therefore mean economic losses due to longer rearing periods and reduced lifetime production (Hartwig & Kilmer, 1984; Drew, 1998). Gunn & Stott (1997) estimated that the loss per calf at risk in a herd with an outbreak of enteritis, accounting for calf mortality, loss in calf value, expenses for extra work, possible veterinary treatment and extra feed to compensate for the retarded growth, could be as high as SEK1 800 (154£). Andrews (2000) reported the average extra rearing cost for a diseased calf in a herd with an outbreak of pneumonia to be approximately SEK500 (43£). This should be compared with the total cost of raising a replacement heifer, which is calculated to be approximately SEK12 000 (Nordgren, 1997). The health of the calves in dairy production is therefore not only a welfare problem but also, an important economic issue.

# Aims

The aims of this thesis were to –

- describe the incidence and treatment of different diseases in 0–90-day-old dairy calves reared under Swedish conditions;

- describe the effect of dam-related risk factors and risk factors in housing and management on the incidence of infectious diseases and on the growth in 0–90-day-old dairy calves; and

- provide a comprehensive view of housing systems, feeding, and management routines used for calves and replacement heifers in Swedish dairy herds.

# Methodological considerations

## Summary of Materials and Methods in Papers I–IV

The data in **Papers I–III** consist of records from an observational study conducted from 1 January 1998 to 31 March 1999 on 122 dairy farms in the county of Skaraborg in south-western Sweden. The farms had a herd size of 28–94 cows and were enrolled in the Swedish official milk and health recording programme. The herds were recruited on the basis of their housing system. Data on housing, feeding and management of the calves were gathered through interviews with the farmers and direct observations by the research staff. Information on the dams' parity, calving performance, morbidity, milk production and somatic cell count was obtained from the official milk and health recording programme. The farmers recorded individually for each calf the dates of birth and weaning, breed, place and time of birth, whether or not the calving had been supervised, colostrum routines and the type of housing system used. They also provided information on length of dry period, occurrence of milk leakage before calving and occurrence of retained placenta in the dams. The farmers measured the calves' heart girth at birth and at weaning. They were also asked to record all disease cases in their heifer calves on individual health cards. In addition, the research veterinarians clinically examined each of the calves during their visits every 2–3 months. The information given by the farmers was checked every 2 months by the research staff.

The data in **Paper IV** consisted of the answers to a questionnaire sent to 1 500 Swedish dairy farmers. The 1 500 herds were randomly selected among all herds in Sweden that had 28–94 cows and were registered in the official milk and health recording programme. The questionnaire gathered general information about the herds and also, information about housing, feeding and management routines from birth to first calving.

The data in **Papers I** and **III** were analysed with multiple regression models using the SAS macro GLIMMIX. The data in **Paper II** were analysed in logistic regression models using MLwiN. In **Paper IV** only descriptive statistics were used.

## Experimental versus epidemiological studies

Experimental and epidemiological studies complement each other. With an experimental study the researcher often has the advantage of being able to present stronger statistical associations than with an epidemiological study (Altman, 1991). Factors that possibly affect the outcome studied can be well controlled and the result presented can often be a reasonably good acceptance or rejection of the null hypothesis. On the other hand, experimental studies are often performed under circumstances that differ considerably from the practical production reality, and an extrapolation is therefore not always straightforward.

The strength of epidemiological studies is that they can better reflect a complex reality. The aetiology of most animal production diseases contains several risk factors and several biological interactions exist between these factors.

Epidemiological studies can facilitate our understanding of these complicated multi-factorial events. One disadvantage of epidemiological studies is that some study designs demand such large sample sizes and efforts by the research staff that the studies become infeasible in terms of economics and staffing needs. A combined study design containing both experimental and epidemiological elements may therefore be suitable.

## Questionnaire studies

There are some critical steps in designing a questionnaire study. One step is to formulate the questions in such a way as to avoid any misunderstanding. In **Paper IV** we therefore asked people in the field (both researchers and producers) to comment on the questionnaire and revised it according to their comments. Since most of the questions (79%) were answered by most of the farmers (98%) in a correct manner and the lowest response rate to a single question was 79% we consider the questionnaire design satisfactory. Of course, the most critical step in a questionnaire study is to make people take the time and effort to answer the questions. Our overall response rate was 58%, which is not optimal, but since the questionnaire was fairly extensive (17 pages) we considered the response rate acceptable and the questionnaire to give a satisfactory picture of the housing, management and feeding routines used for dairy replacement heifers in Sweden.

## Observational studies

### *Sampling of herds and their representative status*

For the purpose of this study as well as for practical and economic reasons, we stated the following seven inclusion criteria for participation in the observational study (**Papers I–III**):

- willingness to participate;
- capability of keeping records;
- location of farm in Skaraborg county;
- membership in the official milk and health recording programme;
- a herd size of 28–94 cows;
- expressed determination to stay in milk production for 5 years; and
- one of the following housing systems: for young calves, single pens, small group pens with a milk bucket feeding system or large group pens with an automatic milk feeding system; for the older heifers, animals tied or kept in pens with slatted floors or straw bedding.

The farmers' capability of keeping thorough records of their calves' performance was considered important since so many of the data were to be registered by the farmers. A previous Swedish study relying on farmers' record-keeping had to exclude large parts of its data owing to inaccuracies (Olsson *et al.*, 1993). By including only voluntary participants in our study and excluding farmers not considered capable of keeping records we hoped to improve the quality of the data. For the same reason, the research staff visited the herds at regular intervals to complete the records. For economic and time consumption reasons, participation was restricted to herds in the county of Skaraborg. The animals that entered the present study will later be followed in a study demonstrating associations between circumstances during the rearing period and life production and longevity. For this continuity, the participating herds also had to be part of the official Swedish milk and health recording programme, which scores items such as annual milk production and causes for culling.

We wanted the herd size to represent the hitherto typical Swedish family dairy farm. In 1998 the chosen herd size of 28–94 cows represented 56% of all Swedish dairy herds. In a statistical comparison between the real studied farms and those in the questionnaire study (**Paper I**) the feeding, housing and management routines did not differ significantly. It was therefore concluded that the farms participating in the observational study were a reasonably representative sample of Swedish dairy farms.

The fact that research staff visited the farms every second month could to some extent have contributed to better management of the study herds than seen in the average Swedish dairy herd. However, we thought the quality of the farmers' data was so important for the study that we decided that this precaution taken to ensure the farmers' registration was justified. To avoid influencing farming methods, apart from the effect of the visits themselves, we did not give any advice on management routines or disease treatment during the study period.

### *Recording of disease*

As described above, project veterinarians visited the herds between five and nine times during the study period and performed clinical examinations of the calves. In order to diagnose the diseases as correctly as possible the farmers recorded only respiratory disease and diarrhoea, based on our definitions of these two diseases, directly on the individual health cards. For all other disease conditions, the farmers recorded the symptoms and the project veterinarians on their visits determined the diagnosis, based on mutual definitions.

### *Body measurements*

Growth was measured as the difference between the heart girth at birth and the heart girth at weaning. Heinrichs, Rogers & Cooper (1992) demonstrated that among the different body measures heart girth is the best estimate for body weight. Also, Sørensen & Foldager (1991) and Andersson (1996) showed a good correlation between the heart girth measurement and body weight although Waltner-Toews *et al.* (1986) argued that heart girth measurements could only be used to show larger variations in weight and weight gains. To maintain a good quality of hearth girth measurements we instructed the farmers on how to use a small balance equivalent to the weight of 2 kg to ensure that the measuring tape was consistently and uniformly stretched in all measurements.

*Statistics*

The number of animals included in an epidemiological study is crucial for the impact of the results. It is, however, equally important that each observation should be made independently. Calves within a herd are probably observed less independently from each other than are calves from different herds (McDermott & Schukken, 1994). The number of herds could, owing to the above-mentioned inclusion criteria, not be increased. Before the study was started sample size calculations were made with estimated intra-class correlations, cluster effects and disease incidence. Towards the end of the study period the calculations were redone, based on the recorded data on growth and disease incidence. The intra-class correlation was calculated and it was found that calves within the herd were more alike regarding growth than regarding disease incidence. The formula from McDermott, Schukken & Shoukri (1994) was used to calculate the cluster effect and the number of animals was found to be sufficient for the analysis of growth and also, for the analysis of total disease incidence. Furthermore, increasing the number of calves per herd would result in a relatively small increase in power but enormous effort and cost. We therefore decided that the number of calves was sufficient. To control for the cluster effect of the herd we included the herd as a random effect, as described by McDermott & Schukken (1994).

In **Paper II** the predictor variables in our model were recorded at the herd level but the outcome variables and the predictor variables included as extra explanatory variables were recorded at an individual level. This type of model has been described as a hierarchical linear model (Bryk & Raudenbush, 1992). The conventional approach to this problem, as reviewed by McDermott & Schukken (1994), is to simply ignore the problem and perform the analysis by disaggregating all data to the lowest level using standard statistical methods. The difficulties created by this approach were acknowledged but remained unsolvable statistically. New software has now solved these difficulties and for the analysis in **Paper II**, we used the software MLwiN. For a description of MLwiN, see Goldstein, Browne & Rasbach (2002).

# Results and Discussion

## Disease incidence

Total mortality from the second day of life was 3.0%. Twenty-three per cent of the calves developed one or more diseases between day 0 and day 90. Enteritis (9.8%) and respiratory disease (7.0%) were the most common diagnoses. Ringworm was diagnosed in 2.5% of the calves while 1.3% suffered from omphalophlebitis and 0.6% suffered from arthritis and 0.5% of the calves developed cheek abscesses or actinosis. In addition, 0.7% of the calves were diagnosed to have diseases other than those mentioned above of presumed infectious origin. Non-infectious digestive disorders were diagnosed in 1.0% of the calves. The age distribution of the two most common diagnoses showed that the occurrence of enteritis had a very distinct peak during the first and second week of life, while the occurrence of respiratory disease increased slowly and became more common after 4 weeks of age. In calves older than 7 weeks of age respiratory disease was more common than enteritis. The median age at onset of disease was 26 days for enteritis and 52 days for respiratory disease (**Paper I**). This is in agreement with the findings of Waltner-Toews, Martin & Meek (1986b) and Sivula *et al.* (1996a).

Previous Swedish studies of disease incidence in dairy calves (Olsson *et al.*, 1993; Viring *et al.*, 1993) showed a low incidence of both enteritis and pneumonia compared with most studies in other countries (Blom, 1982; Waltner-Toews *et al.*, 1986; Gardner *et al.*, 1990; Perez *et al.*, 1990; Sivula *et al.*, 1996a; Virtala *et al.*, 1996a; Wells, Garber & Hill, 1996). The incidence of enteritis found in the present study is in agreement with the result of the previous Swedish study. Olsson *et al.* (1993), however, reported a considerably lower incidence of respiratory disease. This may perhaps be explained by the fact that we used recordings of diseases made by both the farmers and the project veterinarians, whereas Olsson and co-workers only used diagnoses made by the farmers. The fact that the project veterinarians diagnosed half of the cases of respiratory disease in the present study indicates that pneumonia is difficult to detect for farmers. The difference in incidence between the two studies may also be due to differences in the study material, since we not only used larger herds (28–94 versus 20–50 cows) but the herds were also from the area in Sweden that is most densely populated with cattle while Olsson *et al.* studied herds from all over the country.

Arthritis accounted for only 0.6% of morbidity. However, since 50% of calves diagnosed with the disease did not survive beyond 90 days of age arthritis accounted for 10% of the mortality. Arthritis is therefore of greater importance for the animals' welfare and herd economy than indicated by the low incidence risk.

The difference in disease incidence risk between the herds included in this study was considerable (**Paper II**). The total herd-level morbidity ranged from 0.0% to 57.6%, with a median of 21.6% and a central range (20th–80th percentile) of 10.2–34.1%. The herd-level incidence risk for enteritis ranged from 0.0% to 39.4%, with a median of 7.8%. The corresponding numbers for respiratory disease were 0.0–51.7% and a median of 3.0%. The fact that the median of the herd-level respiratory disease incidence risk was so much lower than the total individual incidence risk (7.0%) (**Paper I**) indicates that most herds had a fairly low morbidity. However, a few herds with high morbidity affected the total individual risk for respiratory disease. This may be due in part to the fact that respiratory disease is infectious and will spread between the animals within a herd, but it may also reflect the large impact of the ambient environment. The housing system and the farmers' management routines, for instance, have a large impact on the morbidity in the herd.

## Disease treatments

In the present study 19% of the cases of diarrhoea were treated with oral electrolyte solutions. In 26% of the cases the volume of milk was reduced or the milk was totally withdrawn and in 30% of the cases antibiotic treatment was used (**Paper I**). In a study by Sivula *et al.* (1996a) almost 50% of calves treated for enteritis were treated with only antibiotics while 41% were treated with only oral electrolyte solutions. Treatment of diarrhoeic calves should be supportive and fluid therapy through oral electrolyte solutions is considered to be crucial (Phillips, 1985; McGuirk, 1998). As opposed to what was previously believed, new investigations have found that diarrhoeic calves have sufficient digestive capacity to assimilate the milk and that the calves actually need the milk to avoid an excessive loss of body weight (Garthwaite *et al.*, 1994; McGuirk, 1998). Recent Swedish studies found rotavirus and *Cryptosporidium parvum* to be the most common agents, and *E. coli K99+* to be rare, in the neonatal calf diarrhoea complex (Viring *et al.*, 1993; de Verdier Klingenberg & Svensson, 1998; de Verdier Klingenberg, 1999, Björkman *et al.*, 2004). The use of antibiotics in nearly one-third of the diarrhoea cases in the present study can therefore be questioned, as can the low percentage of cases where oral electrolyte solutions were used. Most diarrhoeic calves are treated by farmers and in the present study only 17% of the treatments of fluids or antibiotics given to calves with diarrhoea were given by veterinarians or following recommendation by a veterinarian. To improve the poor agreement between current recommendations and the treatments actually given the veterinary prophylactic work regarding calf diarrhoea treatment needs to be more active.

In the present study 47% of the cases of respiratory disease were treated with parenteral antibiotics (**Paper I**). In a recent Swedish study all of the *Pasteurella multocida* and *Mannheimia haemolytica* isolated from nasal discharge in pneumonic calves were sensitive to penicillin (Bengtsson & Viring, 2000). *Arcanobacterium pyogenes* and *Staphylococcus aureus* are usually also sensitive to penicillin (Carter & Chengappa, 1991) and penicillin should therefore be the drug of first choice. Unfortunately this is not the reality in Swedish herds; Ortman & Svensson (2004) found that out of 138 calves treated with antibacterial drugs for respiratory disease 38% were treated with penicillin-dihydrostreptomycin, 28% with penicillin and 17% with tetracyclines. Obviously the advisory input needs to be improved also in this area.

## Risk factors for enteritis

The factors associated with an increased odds ratio (OR) for enteritis were housing in a calf pen that was placed along an outer wall, ingesting first colostrum by suckling, receiving the first colostrum from a young cow, being of Swedish Red and White (SRB) breed and being born during the summer season.

In herds where calf pens were placed along an outer wall the calves had an increased risk of suffering from diarrhoea (OR: 1.92) (**Paper II**). This effect may be related to the ambient environment which includes factors such as cold radiation, high relative humidity and damp bedding conditions. In the present study the association between the placing of the calf pens and disease could not be explained by draught.

Improper levels of immunoglobulins in the blood have been reported to be a risk factor for disease (Robison. Stott & DeNise, 1988; DeNise, Robison & Stott, 1989; Wittum & Perino, 1995; Donovan *et al.*, 1998b; Virtala *et al.*, 1999). In the present study, calves receiving colostrum through suckling from the dam were found to be at higher risk for severe enteritis (OR: 1.8) than calves being given the first meal by the farmer (**Paper I**). The presence of the dam has in previous studies been shown to increase the amount of immunoglobulins absorbed (Fallon, 1979; Stott *et al.*, 1979b; Quigley *et al.*, 1995) but it has also been shown that calves left with their mother after birth have a delayed average time to ingestion of their first colostrum and often fail to ingest adequate volumes of colostrum (Besser, Gay & Pritchett, 1991; Michanek & Ventorp, 1993; Rajala & Castrén, 1995; Lidfors, 1996). Since we corrected for the time to first ingestion of colostrum in our model, the results may indicate that it is difficult for farmers to truly recognise the first ingestion of milk in suckling calves.

The risk of enteritis was also increased (OR: 1.6) if the calf received colostrum from a first-lactating cow compared with a third-parity or older cow (**Paper I**). The effects of parity on calves' morbidity have been reported by several authors (Simensen & Norheim, 1983b; Curtis *et al.*, 1988; Wittum *et al.*, 1994a). Devery-Pocius & Larson (1983), Shearer *et al.* (1992), Liberg & Carlsson (1998) and Liberg (2000) have reported that younger cows on average have a lower level of immunoglobulins in their colostrum than do older cows in their third (or more) lactation. A good tool for ensuring a good quality of colostrum is to measure the level of immunoglobulins with a colostrometer since the variation in concentration of immunoglobulin is considerable even between older cows.

The OR in SRB calves for enteritis was 1.6 (**Paper I**). The risk for the SRB calves of suffering from severe diarrhoea was even higher (OR: 2.3) (**Paper I**). Liberg & Carlsson (1998) and Liberg (2000) found that the concentration of IgG in the colostrum sank faster between the first and second milking occasion in SRB cows than in Swedish Holstein (SLB) cows, which could perhaps explain this finding. Furthermore, Kruse (1970) found higher efficiency of absorption of immunoglobulins in Black and White Danish calves than in Red Danish calves and Baumwart, Bush & Mungle (1977) found Holstein calves more efficient than Ayrshire calves in absorbing colostrum.

## Risk factors for respiratory disease and increased respiratory sounds

The factors associated with an increased OR for respiratory disease were a low ammonia concentration, housing in large group pens, birth during the winter season, unsupervised calving, and factors related to the dam (*e.g.* disease during pregnancy, a short dry period, retained placenta and high somatic cell count). The factors associated with an increased OR for moderately to severely increased respiratory sounds were BVDV infection in the herd, being a cross-breed, draught, housing in a large group pen, birth in a cubicle, a group calving pen or at pasture, a poor record-keeping capacity in the farmer, birth during the winter season and birth during the night.

In our study we found a low ammonia concentration to be significantly associated with an increased risk of respiratory disease. This unexpected result is contrary to results reported in other studies (see, *e.g.*, Harry, 1978; Kiorpes, Dubielzig & Beck, 1988). The ammonia concentrations we recorded seemed reasonable in relation to other ambient environment factors measured. However, the observed effect of ammonia may have been confounded by some unknown and unrecorded factor. The ammonia concentration showed a fairly small variation, ranging from 0.3 ppm to 13.5 ppm (mean 5.4 ppm, 20th–80th percentiles 3.3–6.7 ppm), which may have affected the results. The maximum permissible ammonia concentration, according to Swedish animal welfare legislation, is 10 ppm.

Calves in a herd where the farmer was deemed to be a poor record-keeper had an increased risk (OR: 4.48) of suffering from increased respiratory sounds compared with calves in a herd where the farmer was considered to be excellent at keeping records (**Paper II**). The capability of taking accurate records is most probably related to the quality of the total management of the calves, with good record-keepers probably being more thorough in their management, and this could of course have an impact on the disease risk.

Regardless of the housing system used, draught was found to be associated with an increased risk for having moderately to severely increased respiratory sounds at lung auscultation (OR: 3.7) (**Paper II**). Draught has been defined by Wathes, Jones & Webster (1983) as an air speed faster than 0.3 m/s. Draught leads to enhanced heat loss and chilling in cold weather. The stress caused by the heat loss and chilling has been found to negatively affect the immune system, leading to a higher vulnerability to different pathogens (Jennings & Glover, 1952).

Housing in large group pens with an automatic milk feeding system was associated with a higher risk for respiratory disease and for increased respiratory sounds (OR: 2.2 and 2.9, respectively) compared with single-pen housing (**Paper I**). Similar findings have been reported by Maatje *et al.* (1993) and Plath (1999). Respiratory disease is most often caused by viral infections, which are spread by direct contact or aerosol. Older calves are known to be the source of infection in younger calves (Radostits *et al.*, 1999). The age of the calves within a large group pen in our study usually ranged from 1 week to 3 months, and the close contact between many calves of different ages probably contributed to the increased risk of respiratory disease in calves kept in large group pens. There was, however, no difference between calves in different housing systems regarding the age at which the respiratory disease was diagnosed or the severity of the cases.

Calves in herds in which either antibodies against BVDV or persistently BVDV-infected animals were present at the start of the study ran an increased risk of having moderately to severely increased respiratory sounds at lung auscultation (OR: 2.4) compared with herds free from BVDV infection (**Paper II**). Larsson, Niskanen & Alenius (1994) found the mortality and the percentage of calves treated by veterinarians for respiratory disease and/or enteritis to be significantly higher in calves born during a period of BVDV introduction to the herd than in calves born the previous year or the year after (when calves persistently infected with BVDV were present for most of the period). Bovine viral diarrhoea virus appears to be an immunosuppressant agent which may increase the susceptibility of the host to other respiratory or enteric pathogens (Potgieter *et al.*, 1984; Wray & Roeder, 1987). According to the BVDV control programme in Sweden, the number of herds infected with BVDV is rapidly decreasing.

The ORs for calves born during the autumn and winter period of suffering from respiratory disease were 2.3 and 2.0, respectively (**Paper I**). This is in accordance with previous findings (Dennis, 1986). The increased risk could be a reflection of the increased number of animals in the building since all animals are kept indoors during the winter period. This probably increases the infectious disease pressure for the young calves. Likewise, the poorer climatic conditions (*e.g.* increased humidity) during the winter compared with the summer period in combination with the increased number of animals could contribute to the increased susceptibility to respiratory disease (Asaj, 1997). The increased humidity also leads to a prolonged survival time for different viruses in the ambient environment, which means that the viruses can travel longer distances with the air streams without losing their virulence (Dennis, 1986).

In the present study the risk of suffering from respiratory disease was higher in calves born to cows with a short dry period (≤45 days) than it was in calves born to cows with an average or long dry period (>75 days) (OR: 1.9) (**Paper III**), perhaps because of lower concentrations of IgG in the colostrum of cows with a short dry period (Logan, Meneely & Lindsay, 1981). On the other hand, Liberg & Carlsson (1998) and Liberg (2000) did not find an effect of the length of the dry period on the concentration of IgG in the colostrum. The variation in number of days dry in their study material was, however, fairly small.

A calf born in a cubicle, in a group maternity pen or on pasture (OR: 1.8) had an increased risk of suffering from moderately to severely increased respiratory sounds compared with calves born in an individual maternity pen (**Paper I**). Michanek & Ventorp (1993) showed that at 36 hours after birth calves born in group calving pens had a lower concentration of IgG in serum than did calves born in individual calving pens, probably due to the suckling of a cow without colostrum. Another explanation may be that the hygienic standard tends to be less good in a cubicle or a group maternity pen than in an individual maternity pen.

Calves born to cows with a retained placenta after parturition or to cows that were diseased 50–280 days before calving had a higher relative risk (OR: 1.5–1.8) of developing respiratory disease than did calves born to healthy cows (**Paper III**). The higher risk in calves born to such cows of suffering from respiratory disease may be explained by an unfavourable foetal period compared with that of calves born to healthy mothers.

The OR for calves born in an unattended birth of suffering from respiratory disease was 1.4 (**Paper I**). As discussed previously, this could have been an effect of the calves' difficulties in suckling the first colostrum from their mother without human help (Besser, Gay & Pritchett, 1991; Michanek & Ventorp, 1993; Rajala & Castrén, 1995; Lidfors, 1996). Another explanation may be that the unattended birth may have been more difficult for both the cow and the calf since no human assistance was given. A difficult calving has been found to negatively affect the colostrum ingestion by the calf (Logan, McBeath & Lowman, 1974).

## Risk factors for other infectious diseases

The factors associated with an increased OR for infectious diseases other than diarrhoea and respiratory disease were receiving colostrum from a young cow, absence of draught, being kept in a calf pen that was placed along an outer wall and being born during the night.

The importance of colostrum was again emphasised in the analysis of risk factors for infectious diseases (**Paper I**). The highest OR was found in calves that had received colostrum from a second-lactating cow (OR: 1.6). The different concentration of immunoglobulins in the colostrum in cows of different age has been discussed previously (Devery-Pocius & Larson, 1983; Shearer *et al.*, 1992; Liberg & Carlsson, 1998; Liberg, 2000). Liberg & Carlsson (1998) and Liberg (2000) found the lowest concentration of immunoglobulins in colostrum from second-lactating cows.

Calves born during the night were found to have an increased risk of suffering from other infectious disease (OR: 1.5) compared with calves born during the day (**Paper I**). This could perhaps also be explained by the colostrum routines, since calves born during the night may not receive colostrum until the next day, which of course means a prolonged period between birth and first intake of colostrum. The closure of the calf's intestine to absorption of immunoglobulin begins soon after birth and increases rapidly after 12 hours (Stott *et al.*, 1979a). Another explanation may be that calves born during the night will perhaps spend their first hours of life in a dirty cubicle or a tie-stall, which means that the number of micro-organisms in the environment will be increased.

The unexpected finding in the present study that the absence of draught was associated with an increased risk of other infectious disease is difficult to explain (**Paper II**).

## Factors affecting growth

In the present study the following factors were found to negatively affect growth: being of SRB breed, disease, being housed in a large group pen, first parity of the dam, retained placenta and difficult calving.

Age at first calving is mostly determined by growth from birth to sexual maturity. The optimal growth between weaning and puberty has been much debated and contradictory results of the effect of the growth in this period on the subsequent milk production have been published (see, *e.g.*, Sejrsen *et al.*, 1982; Mäntysaari *et al.*, 1995; Radcliff *et al.*, 1997; van Amburgh *et al.*, 1998; Petitclerc *et al.*, 1999; Abeni *et al.*, 2000). A high average daily weight gain during the pre-weaning period has not been found to negatively affect subsequent milk production (Foldager & Krohn, 1991; Bar-Peled *et al.*, 1997). Andersson (1996) found a positive association between growth during the first 74 days of life and the age and weight at first calving. A high weight gain during the pre-weaning period could therefore only be considered positive and worth achieving.

The mean ± standard deviation (SD) growth between birth and 90 days of age in the present study was 0.30 ± 0.06 cm/day (**Paper III**). This is equivalent to approximately 600 g per day. Sivula *et al.* (1996b) reported a mean average weight gain of 820 g per day from birth to 16 weeks of age in American Holstein calves. A slightly lower average weight gain (710 and 740 g per day, respectively) was reported by Bar-Peled *et al.* (1997) and Donovan *et al.* (1998a). An average daily weight gain of 560 g during the first 3 months was reported by Virtala *et al.* (1996b). In the present study we found a difference in growth between the two breeds studied. Swedish Holstein calves grew faster than SRB calves, 580 g versus 610 g per day. The mean herd-level growth ranged from 400 g to 920 g per day, with a central range (20th–80th percentile) of 540–680 g per day. A new Swedish recommendation is that calves should gain between 600 g and 900 g per day from day 0 to day 90 and thereafter between 650 g and 750 g per day until pregnancy, to reach the desired age of 24 months at first calving (Almér, 2001). Fifty per cent of the 122 herds included in the present study had a mean growth of 600 g or more per day, which indicates that there is much improvement to be made within this area and that most of the farmers do not use the full biological potential of their calves.

Disease was found to be negatively associated with growth (**Paper III**), which is in agreement with several previous studies (Thomas, Wood, Longland; 1978; Wittum *et al.*, 1994b; Ganaba *et al.*, 1995; Virtala *et al.*, 1996b; Donovan *et al.*, 1998a). Compared with healthy animals, calves suffering from respiratory disease grew 25 g less per day, calves suffering from enteritis grew 13 g less per day and calves suffering from both diseases grew 90 g less per day, which is equivalent to 2.2, 1.2 and 8.1 kg less during the 90-day period. The difference in growth between calves suffering from respiratory disease and calves suffering from enteritis may be explained by the duration of the disease. In the present study, calves suffering from respiratory disease during their first 3 months of life were diseased for an average of 6 days while calves suffering from enteritis on average had 3 disease days. Gitau *et al.* (1994) found the compensatory growth during the month following recovery from a clinical disease to be insufficient, but Busato *et al.* (1997) and Sivula *et al.* (1996a) reported contradictory results on this topic.

In our study, calves in small group pens were found to grow approximately 30 g more per day than calves in single pens and approximately 80 g more per day than calves in large group pens (**Paper III**). This is equivalent to 2.7 and 7.2 kg, respectively, over the 90-day period studied. A higher growth in calves raised in small group pens compared with calves raised in individual pens was previously reported by Warnick, Arave & Mickelsen (1977) and Simensen & Norheim (1983b). This may be explained by an increased feed intake due to stimulation by pen mates, as reported by Heffernan & Schacke (1976) and Warnick, Arave & Mickelsen (1977). The finding in the present study that calves in small group pens on average grew more per day than did calves in large group pens could not be explained by different feeding levels since the calves in the large group pens on average received slightly more milk than did the calves in the small group pens (5.6 L per day compared with 5.2 L of milk per day). Fiems *et al.* (1982) did not find a significantly higher growth rate in calves in large group pens than in calves in single pens, even when the calves in the large group pen were fed milk *ad libitum*. One factor that may contribute to a lower average growth in calves housed in large group pens is that they might play and move about more than do calves in small group pens or individual pens (Jensen, 1999). Bøe & Faerevik (2003) in a review of the literature on the social behaviour of calves, heifers and cows found that grouping and re-grouping of calves could be a stress factor, particularly for the individual entering a group. This could also contribute to a lower weight gain. Furthermore, it is likely that differences in subclinical morbidity affect the growth rate. In the present study the incidence risk of clinical respiratory disease was higher in calves housed in large group pens than it was in calves housed in individual pens (**Paper I**). It is therefore likely that the occurrence of subclinical disease also was higher in this group of calves.

Calves from first-parity cows were found to grow more slowly than calves from older cows (**Paper III**). Since almost all of the calves in the study received colostrum from their own mother the effect of parity on growth could perhaps be explained by the fact that the colostrum from primiparous cows has lower concentrations of IgG than does that of older cows (Devery-Pocius & Larson, 1983; Shearer *et al.*, 1992; Liberg & Carlsson, 1998; Liberg, 2000) and that calves of primiparous cows therefore suffer from an increased risk of not receiving proper serum concentrations of immunoglobulins, as discussed previously. Since clinical disease was included in the model the retarded growth in calves from younger dams could perhaps be explained by the effect of subclinical disease on growth.

## Housing and management routines

We found the place of birth to be associated with a higher risk for moderately to severely increased respiratory sounds (**Paper I**). In the questionnaire study only 40% of the herds used special maternity pens for calving, and among these, 18% used group calving pens (**Paper IV**). According to the Swedish animal welfare legislation in place since 1993, dairy herds must have one maternity pen for every 30 cows. From previous studies it is known that the use of a calving pen has positive effects on the offspring and its absorption of immunoglobulins from the colostrum (Fallon, 1979; Stott *et al.*, 1979b; Quigley *et al.*, 1995). However, as discussed previously, one important factor to consider when using maternity pens is the calf's difficulty in finding the cow's teats within the first, important hours after birth (Besser, Gay & Pritchett, 1991; Michanek & Ventorp, 1993; Rajala & Castrén, 1995; Lidfors, 1996). Ventorp & Michanek (1990) found a short distance from the udder to the floor to be a reason for prolonged teat-seeking. To ensure that the calf receives adequate amounts of colostrum when kept in a calving pen, it should be fed manually. The use of group calving pens also offers calves the possibility to suckle a cow without colostrum, which leads to poor passive immunity defence (Michanek & Ventorp, 1993). The hygiene of a group calving pen should also be considered. Fluids from a birth will create a favourable environment for infectious agents. Furthermore, if one calf in the pen suffers from diarrhoea this will further increase the number of pathogens in the ambient environment. Of the 122 herds included in the present observational study single or group calving pens were used in 59 herds. On average these calving pens were cleaned before the next calving in 74% of the cases. Group calving pens are almost never cleaned before the next calving. The use of group pens for calving may therefore be questioned.

In agreement with previous studies (Devery-Pocius & Larson, 1983; Besser, Gay & Pritchett, 1991; Shearer *et al.*, 1992; Michanek & Ventorp, 1993; Rajala & Castrén, 1995; Lidfors, 1996; Liberg & Carlsson, 1998; Liberg, 2000) the colostrum routines were found to be of utmost importance for the prevention of diseases, as discussed previously (**Papers I–III**). One important aspect of the colostrum routines has been shown by Liberg & Carlsson (1998) and Liberg (2000), among others. They found that milk from the second milking of the cow on average contains only 55% of the level of IgG found in milk from the first milking. This means that the risk of insufficient levels of immunoglobulin in the blood of the calf increases when the farmer does not routinely utilise colostrum from the first milking only. Thirty-nine per cent of the farmers in the questionnaire study saved milk from the first milking occasion after calving for the calves' first two meals. In 54% of the herds milk from the first two milkings was used for the calves' first two meals and in 7% of the herds milk from later milkings than the second was also used (**Paper IV**).

During the colostrum period the farmers in general gave their calves two meals of 2.5 L of milk per day during their first days of life (**Paper IV**). This is sufficient if the colostrum is of good quality, that is, if it contains more than 50 g immunoglobulin per litre of milk (Liberg & Carlsson, 1998; Liberg, 2000), but the total volume should be increased if the colostrum contains less immunoglobulin per litre of milk. The calves should have ingested at least 3–400 g of immunoglobulins within the first 48 hours (Roy, 1980).

After the colostrum period the calves in the present study generally received 5 L of milk per day divided into two meals. Dairy calves that are allowed to freely suckle from their mother are known to drink 8–10 L of milk per day (Widebeck, 1997). In 44% of the herds in the present study the calves were fed whole milk and in 42% they were fed milk replacements. Combinations of the two alternatives were used in the remaining herds. Compared with the earlier Swedish survey by Stenebo (1995) the feeding of whole milk to Swedish dairy calves throughout the entire pre-weaning period was more common in the present study. This may be due to differences in the payment system for whole milk and to the price of milk replacements. Waltner-Toews, Martin & Meek (1986b) found an increased risk of morbidity when milk replacements were used, which could be due at least in part to poor preparation routines. Perez *et al.* (1990) did not find any association between type of milk and diarrhoea. Almost all farmers (98%) in our study stated that they heated the whole milk before feeding. For this purpose, 56% used a water-bath, 20% added hot water to the milk, 12% used an immersion heater and the remainder used a combination of these alternatives. The routine of heating the whole milk by adding hot water has been reported to negatively affect the coagulation process of the milk in the abomasum (Roy, 1990).

The housing system was found to be another factor that could have an impact on the disease risk for calves (**Paper I**) as well as on growth (**Paper III**). The results from the questionnaire study showed that 68% of the farmers housed their calves in individual pens, 13% used large group pens with an automatic milk feeding system and 15% used small group pens without an automatic milk feeding system. Since the herds in which a large group pen with an automatic milk feeding system was used were generally larger (on average consisting of 58 cows) than the herds kept in individual pens or small group pens (on average numbering 42–44 cows) 16% of the calves were housed in large group pens, 64% in individual pens and 18% in small group pens (**Paper IV**). Earlier surveys performed in Sweden (Bernes, Martinsson & Pettersson., 1986; Norrman, 1990; Stenebo, 1995) found the individual pen to be even more frequently used, with more than 90% of the herds utilizing this housing system. The lower percentage in the present study may express a tendency in the last decade towards an increased use of group pens in Sweden, probably partly due to the increasing number of animals on the dairy farms in the country. The increasing use of group pens is not an entirely negative development; Webster *et al.* (1985) and Jensen (1999) found the group housing systems to have positive effects on the social behaviour of calves. The recommendations for the large group pens should, however, be changed so that both the age difference between the calves and the number of calves in the pens are decreased. More research will be needed in this area to determine optimal group size. In our study, calves in large group pens had a significantly increased risk of respiratory disease, a tendency for a decreased risk of enteritis (although the cases of enteritis were significantly more severe) and significantly lower growth compared with calves in single pens and small group pens. Calves in small group pens were significantly younger at the onset of enteritis and had a significantly increased growth compared with calves in single pens. When both the health status and the growth of the calves were considered the small group pen with three to six calves appeared to be the best housing alternative in our study (**Papers I and III**).

Another important aspect of housing is whether the calves are housed together with older cattle or in a separate section of the building. Aerosol contact between calves and older cattle has been found to be a risk factor for increased morbidity among the calves (Phillippo *et al.*, 1987; Fourichon, Beaudeau & Seegers, 1997; Virtala *et al.*, 1999). It is also possible to create a better climatic environment for the calves if they are housed separately. For instance, the temperature could be increased for the younger calves. Simensen (1981), however, explained the high level of ammonia, the low temperature and the high air humidity found when the calves were housed in a separate building to be due to the often poor ventilation in separate calf stables. Dennis (1986) in reviewing surveys and experimental work on temperature and humidity proposed that humidity affects the survival of airborne pathogens. A high level of ammonia has also been found to increase the risk of respiratory disease within a herd (Harry, 1978; Kiorpes, Dubielzig & Beck, 1988) although this was not found in the present study (**Paper II**). In the questionnaire study 64% of the herds housed their calves together with older cattle while in 16% of the herds the calves were housed separately. Unfortunately 20% of the answers to this question had to be excluded because they could not be interpreted (**Paper IV**).

In the questionnaire study we also investigated the housing systems used for older heifers. Various combinations of housing systems were used and the animals were often moved between different housing systems. Between weaning and breeding 53% of the farms kept their heifers on a slatted floor for some of the time, 29% of farms kept their heifers in litter pens for some of the time and 7% kept their heifers tied up during the entire period. The median age at which calves were transferred to pens with a slatted floor (in herds in which such a system was used) was 2 months. Replacement heifers that were tied for some time during the period from birth to calving had a median age of 12 months when they first were tied up in a stanchion barn. Between breeding and first calving the heifers were kept on a slatted floor for some time in 24% of herds and in litter pens in 27% of herds while in 36% the heifers were tied during the entire period (**Paper IV**). The use of pens with slatted floors has been found to affect both the behaviour of the animals and their health. According to a preference study by Bäckström (1977), calves never choose to lie down on a slatted floor without straw if they have access to areas with litter. Lidfors (1992) reported more abnormal rising behaviours in bulls kept on a slatted floor than in bulls kept in litter pens. Hannan & Murphy (1983) found a higher incidence of diseases in cattle kept on a slatted floor than in cattle in litter pens. Frankena *et al.* (1993) found that replacement heifers housed on litter had better claw health than did replacement heifers housed on a slatted floor. Hindhede *et al.* (1996) found a significant decrease in the prevalence of heel horn erosion with access to bedding compared with only a slatted floor. Other studies have shown that housing of heifers in litter pens is not entirely beneficial with regard to claw health. An overgrowth of the claws in calves housed in litter pens, due to the modest wear of claw horn, was reported by Vermunt & Greenough (1995). Webster (2000) reported that the heels of replacement heifers housed on litter frequently show deep erosions, probably due to chemical effects. Being tied also affects the behaviour of animals. Redbo (1990) and Jensen (1999) both found an increased rate of stereotypical behaviours in tied-up heifers. According to the Swedish animal welfare legislation of 1997, calves must be kept loose up to at least 6 months of age. The average age for replacement heifers to be tied in the present study was 12 months but the 80% central range varied from 3 months to 23 months.

The cost of raising replacement heifers is an important part of the milk-production economy (Annexstad, 1986; Heinrichs, 1993) and it is therefore essential that heifers start to produce milk at an optimal age. The mean age at first calving in the questionnaire study was 27.9 months but the range was 20.0 to 40.5 months (**Paper IV**). The age at calving depends on the age at first AI or covering. Different criteria may be used to determine the time for first AI. Thirty-seven per cent of the herds used age as criterion for determining the time for first AI or covering. The median age used in these herds was 16 months. In 18% of the herds heart girth was instead used to determine the time for first insemination or covering. In these herds the median heart girth used for this purpose was 160 cm. The recommendation in Sweden has been a minimum heart girth of 155 cm for SRB and 160 cm for SLB animals (Widebeck, 1997).

# Conclusions

This thesis provides additional support for how important conditions and the course of events during the calf's first days of life are to the animal's subsequent health, and further emphasises the importance of good colostrum routines, such as hand feeding the calf the first colostrum and using colostrum from older cows. It demonstrates the positive health effects of being born in an individual calving pen compared with a cubicle or a group calving pen and the importance of the dam's status for the calf's health and growth. Housing in large group pens with an automatic milk feeding system is identified as a health hazard and the health problems are shown not only to be a welfare problem but also, to have a negative effect on the growth rate of the calves. The increased risk of respiratory morbidity associated with BVDV infection is shown in a large-scale study. The need for improved advisory input on treatment of calf diseases is demonstrated since in the herds studied both diarrhoeic and pneumonic calves were found to be inappropriately treated in a majority of cases. The results also show that the growth of the Swedish dairy calves studied was fairly low compared with their biological capacity.

This thesis has also presented the first extensive survey of housing, feeding and management routines for calves and replacement heifers practised on Swedish dairy farms, and identifies the need for improvement in several areas.

# Practical advice to farmers

- Calving should be supervised to give the calf the best possible start in life. A camera may be a solution to practical problems.
- A clean single calving pen is the best indoor alternative and it provides the calf with a good environment to be born in. The use of group calving pens should be avoided. The first meal of colostrum should be given by the farmer within the first 4 hours.
- The quality of the colostrum is crucial. A colostrometer should be used to establish the concentration of immunoglobulin in the colostrum. If this is not possible, colostrum from older cows (cows with three or more lactations) should be used.
- Colostrum from the first milking after calving should also be used for the second meal.
- Whole milk should not be heated by adding hot water. It is better to use an immersion heater or a water-bath.
- The increased use of large group pens for young calves requires strict routines to avoid the health problems associated with this type of housing. It is important to minimise the group size and keep the age difference as small as possible within the group. The hygienic routines are also very important.
- Calf pens should be separated from outer walls and should be free from draught.
- Calves should be closely observed every day to detect diseases as early as possible, especially respiratory disease which has proved difficult to detect.
- Calves with arthritis should be treated immediately with antibiotics. Calves with enteritis should be treated with electrolyte solutions and their milk should not be withdrawn. Diarrhoeic calves should not be routinely treated with antimicrobials. If a bacterial infection is suspected in a pneumonic calf, penicillin should be the drug of first choice.
- The calf's full potential of growth should be used during the first 3 months. The amount of milk given should be increased to improve growth. To ensure that the calf also starts to eat roughage and concentrate it is important to offer feed stuff of a good hygienic and energetic quality.

# Sammanfattning

Avhandlingen beskriver och diskuterar resultaten från en observationsstudie utförd i mjölkproducerande besättningar i före detta Skaraborgs län i sydvästra Sverige samt en landsomfattande enkätstudie. I observationsstudien följdes hälsan hos 3081 kvigkalvar, födda i 122 besättningar 1998, under levnadsdag 0 till 90. Kalvarnas bröstomgång mättes vid födelsen och vid avvänjningen. Deras genomsnittliga tillväxt var 600 gram per dag. Sjukdomsförekomsten registrerades av djurägarna och av projektveterinärerna som undersökte kalvarna varannan till var tredje månad. Den totala sjukligheten var 23%; diarré och luftvägslidande var de vanligaste diagnoserna. Vi undersökte effekten av kalvrelaterade, besättningsrelaterade och ko-relaterade faktorer på tillväxten och förekomsten av infektiösa sjukdomar under de första 90 levnadsdagarna. Kalvboxar placerade längs yttervägg, första råmjölksgivan genom digivning, råmjölk från en yngre ko, SRB-ras och födelse under sommarperioden var faktorer signifikant associerade med en ökad risk för diarré. Låg ammoniakkoncentration, drag, infektion med bovint virus diarré virus i besättningen, mindre god registreringsförmåga hos djurägaren, korsningsras, inhysning i stor gruppbox med automatisk kalvamma, födelse under vinterperioden, födelse i en lösdrift, en gruppkalvingsbox eller på bete, obevakad kalvning och faktorer relaterade till kons hälsa var faktorer signifikant associerade med en ökad risk för luftvägslidande. Råmjölk från en yngre ko, frånvaro av drag, kalvboxar placerade längs yttervägg och födelse nattetid var faktorer signifikant associerade med ökad risk för andra infektionssjukdomar. Tillväxten påverkades negativt av SRB-ras, inhysning i stor gruppbox med automatisk kalvamma, svår kalvning, första-kalvare och kvarbliven efterbörd.

Enkäten skickades ut till 1500 mjölk producerande besättningar i Sverige. Frågorna gällde generell information om besättningen samt rutiner från födelse till inkalvning för kalvar och rekryteringskvigor. Enkäten är den första större undersökningen av vilka inhysningsystem, utfodrings- och skötselrutiner som används på svenska mjölkgårdar. Den identifierar flera områden inom vilka ökad rådgivning behövs, till exempel råmjölksrutiner, uppvärmning av helmjölk och inhysning av kalvar och kvigor. I detta förhoppningsvis förbättrade rådgivningsarbete borde resultaten från observationsstudien kunna vara användbara.

# References

Abeni, F., Calamari, L., Stefanini, L. & Pirlo, G., 2000. Effects of daily gain in pre- and postpubertal replacement dairy heifers on body condition score, body size, metabolic profile and future milk production. *Journal of Dairy Science 83*, 1468–1478.
Acres, S.D., Saunders, J.R. & Radostits, O.M., 1977. Acute undifferentiated neonatal diarrhea of beef calves: the prevalence of enterotoxigenic *E. coli*, reo-like (rota) virus and other enteropathogens in cow-calf herds. *Canadian Veterinary Journal 18*, 113–121.
Adair, B.M., Bradford, H.E., McNulty, M.S. & Foster, J.C., 1999. Cytotoxic interactions between bovine parainfluenza type 3 virus and bovine alveolar macrophages. *Veterinary Immunology Immunopathology 67*, 285–294.
Al-Mashat, R.R., & Taylor, D.J., 1980. Production of diarrhoea and dysentery in experimental calves by feeding pure cultures of *Campylobacter fetus subspecies jejuni*. *Veterinary Record 107*, 459–464.
Almér, M., 2001. Rekryteringskvigan – en litteraturstudie. (The Dairy Replacement Heifer – a Study of the Literature.) *T-No. 2630, Svensk Mjölk*, Hållsta, Sweden (In Swedish).
Altman, D.G., 1991. *Practical Statistics for Medical Research*. Chapman & Hall, London, Great Britain.
Ames, T.R., 1997. Dairy calf pneumonia. The disease and its impact. *Veterinary Clinics of North America: Food Animal Practice 13*, 379–391.
Ames, T.R., Markham, R.J.F., Opuda-Asibo, J., Leininger, J.R. & Maheswaran, S.K., 1985. Pulmonary response to intratracheal challenge with *Pasteurella haemolytica* and *Pasteurella multocida*. *Canadian Journal of Comparative Medicine 49*, 395–400.
Andersson, T., 1996. Rekryteringskvigor för mjölkproduktion – uppfödningsmodellens betydelse för produktionen. (Dairy Replacement Heifers in Milk Production – the Significance of the Rearing Strategy for the Production.) *Degree project, Swedish University of Agricultural Sciences*, Uppsala, Sweden (In Swedish).
Andrews, A.H., 2000. Calf pneumonia costs! *British Veterinary Cattle Practice 8*, 109–114.
Annexstad, J., 1986. Raise replacements economically. *Dairy Herd Management 13*, 20–22.
Asaj, A., 1997. Roof ventilation in the prevention of pneumonia in fattening calves. *Proceedings of the IXth International Congress on Animal Hygiene*, 17–21 August, Helsinki, Finland, 48–51.
Baker, J.C., 1987. Bovine viral diarrhea virus: a review. *Journal of American Veterinary Medicine Association 190*, 1449–1458.
Baker, J.C., & Frey, M.L., 1985. Bovine respiratory syncytial virus. *Veterinary Clinics of North America: Food Animal Practice 1*, 259–275.
Baker, J.C., Ellis, J.A. & Clark, E.G., 1997. Bovine respiratory syncytial virus. *Veterinary Clinics of North America: Food Animal Practice 13*, 425–454.
Bar-Peled, U., Robinzon, B., Maltz, E., Tagari, H., Folman, Y., Bruckental, I., Voet, H., Gacitua, H. & Lehrer, A.R., 1997. Increased weight gain and effects on production parameters of Holstein heifer calves that were allowed to suckle from birth to six weeks of age. *Journal of Dairy Science 80*, 2523–2528.
Baumwart, A.L., Bush, J.L. & Mungle, M., 1977. Effect of potassium isobutyrate on absorption of immunoglobulins from colostrum by calves. *Journal of Dairy Science 60*, 759–762.
Bendixen, P.H., Vilson, B., Ekesbo, I. & Åstrand, D.B., 1986. Disease frequencies of tied-zero grazing dairy cows and of dairy cows on pasture during summer and tied during winter. *Preventive Veterinary Medicine 4*, 291–306.
Bengtsson, B., & Viring, S., 2000. Luftvägsinfektioner – "Projekt, panorama och behandlingsstrategier". (Respiratory Infections – "Project, Panorama and Treatment Strategies.) *Proceedings of the Svenskt Veterinärmöte*, 9–10 November, Uppsala, Sweden, 153–157 (In Swedish).
Bernes, G., Martinsson, K. & Pettersson, T., 1986. Kviguppfödning i praktiken. (Raising of the Dairy Heifer.) *Report No. 7, Department of Agricultural Research for Northern*

*Sweden*, *Swedish University of Agricultural Science*, Röbäcksdalen, Umeå, Sweden, (In Swedish).
Besser, T.E., Gay, C.C. & Pritchett, L., 1991. Comparison of three methods of feeding colostrum to dairy calves. *Journal of the American Veterinary Medicine Association 198*, 419–422.
Bitsch, V., Friis, N.F. & Krogh, H.V., 1976. A microbiological study of pneumonic calf lungs. *Acta Veterinaria Scandinavica 17*, 32–42.
Björkman, C., Svensson, C., Christensson, B. & de Verdier, K., 2004. *Cryptosporidium parvum*, *Giardia intestinalis* and other enteric pathogens in Swedish dairy calves. *Acta Veterinaria Scandinavica*, In press.
Blom, J.Y., 1982. The relationship between serum immunoglobulin values and incidence of respiratory disease and enteritis in calves. *Nordic Veterinary Medicine 34*, 276–281.
Blomqvist, A., 1895. *Handledning i djurskyddslära för hemmet och skolan. (Animal Welfare Manual for Homes and Schools.)* C.E. Fritzes Kungliga Hofbokhandel, Stockholm, Sweden (In Swedish).
Britney, J.B., Martin, S.W., Stone, J.B. & Curtis, R.A., 1984. Analysis of early calfhood health status and subsequent dairy herd survivorship and productivity. *Preventive Veterinary Medicine 3*, 45–52.
Bruning-Fann, C., & Kaneene, J.B., 1992. Environmental and management risk factors associated with morbidity and mortality in perinatal and pre-weaning calves: a review from an epidemiological perspective. *Veterinary Bulletin 62*, 399–413.
Bryk, A.S., & Raudenbush, S.W., 1992. *Hierarchical Linear Models*. Sage, Newbury Park, CA, USA.
Busato, A., Steiner, L., Martin, S.W., Shoukri, M.M. & Gaillard, C., 1997. Calf health in cow-calf herds in Switzerland. *Preventive Veterinary Medicine 30*, 9–22.
Bäckström, M., 1977. Närmiljöns inverkan på beteende hos kalvar och ungdjur av mjölkkoras. (Influence of the Local Environment on the Behaviour of Dairy Calves and Young Stock.) *Report No. 24, Department of Agricultural Biosystems and Technology*, *Swedish University of Agricultural Science*, Uppsala, Sweden, ISBN: 91-7088-782-9 (In Swedish)
Bøe, K.E., & Faerevik, G., 2003. Grouping and social preferences in calves, heifers and cows. *Applied Animal Behaviour Science 80*, 175–190
Carter, G.R., & Chengappa, M.M., 1991. *Essentials of Veterinary Bacteriology and Mycology*. 4th ed. Lea & Febiger, Philadelphia, PA, USA.
Chua, B., Coenen, E., van Delen, J. & Weary, D.M., 2002. Effects of pair versus individual housing on the behaviour and performance of dairy calves. *Journal of Dairy Science 85*, 360–364.
Corbeil, L.B., Widders, P.R., Gogolewski, R., Arthur, J., Inzana, T.J. & Ward, A.C.S., 1986. *Haemophilus somnus*: bovine reproductive and respiratory disease. *Canadian Veterinary Journal 27*, 90–93.
Correa, M.T., Curtis, C.R., Erb, H.N. & White, M.E., 1988. Effect of calfhood morbidity on age at first calving in New York Holstein herds. *Preventive Veterinary Medicine 6*, 253–262.
Curtis, C.R., Scarlett, J.M., Erb, H.N. & White, M.E., 1988. Path model of individual-calf risk factors for calfhood morbidity and mortality in New York Holstein herds. *Preventive Veterinary Medicine 6*, 43–62.
Curtis, C.R., White, M.E., Erb, H.N., 1989. Effects of calfhood morbidity on long-term survival in New York Holstein herds. *Preventive Veterinary Medicine 7*, 173–186.
de la Fuente, R., Lúzon, M., Ruiz-Santa-Quiteria, J.A., García, A., Cid, D., Orden, J.A., García, S., Sanz, R. & Gómez-Bautista, M., 1999. *Cryptosporidium* and concurrent infections with other major enteropathogens in 1 to 30-day old diarrheic dairy calves in central Spain. *Veterinary Parasitology 80*, 179–185.
de Leeuw, P.W., Ellens, D.J., Straver, P.J., van Balken, J.A.M., Moerman, A. & Baanvinger, T., 1980. Rotavirus infections in calves in dairy herds. *Research of Veterinary Science 29*, 135–141.
Dellmeier, G.R., Friend, T.H. & Gbur, E.E., 1985. Comparison of four methods of calf confinement. II. Behaviour. *Journal of Animal Science 60*, 1102–1109.

DeNise, S.K., Robison, J.D. & Stott, G.H., 1989. Effects of passive immunity on subsequent production in dairy heifers. *Journal of Dairy Science 72*, 552–554.
Dennis, M.J., 1986. The effects of temperature and humidity on some animal diseases – a review. *British Veterinary Journal 142*, 472–485.
de Verdier Klingenberg, K., 1999. Neonatal calf diarrhoea with special reference to rotavirus infections; significance, epidemiology and aspects of prevention. *Acta Universitatis Agriculturae Sueciae Veterinaria 54*, Doctoral thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.
de Verdier Klingenberg, K., 2000. Enhancement of clinical signs in experimentally rotavirus infected calves by combined viral infections. *Veterinary Record 147*, 717–719.
de Verdier Klingenberg, K., & Svensson, L., 1998. Group A rotavirus as a cause of neonatal calf enteritis in Sweden. *Acta Veterinaria Scandinavica 39*, 195–199.
Devery-Pocius, J.E., & Larson, B.L., 1983. Age and previous lactations as factors in the amount of bovine colostral immunoglobulins. *Journal of Dairy Science 66*, 221–226.
Done, J.T., Terlecki, S., Richardsson, C., Harkness, J.W., Sands, J.J., Patterson, D.S., Sweasey, D., Shaw, I.G., Winkler, C.E. & Duffell, S.J., 1980. Bovine virus diarrhoea-mucosal disease virus: pathogenicity for the fetal calf following maternal infection. *Veterinary Record 106*, 473–479.
Donovan, G.A., Dohoo, I.R., Montgomery, D.M. & Bennet, F.L., 1998a. Calf and disease factors affecting growth in female Holstein calves in Florida, USA. *Preventive Veterinary Medicine 33*, 1–10.
Donovan, G.A., Dohoo, I.R., Montgomery, D.M. & Bennet, F.L., 1998b. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. *Preventive Veterinary Medicine 34*, 41–46.
Drew, B., 1998. Targets for rearing dairy heifers – weaning to calving. *In Practice 20*, 35–39.
Dubey, J.P., Speer, C.A. & Fayer, R., 1990. *Cryptosporidosis of Man and Animals*. CRC Press, Boston, MA, USA.
Eigenmann, U.J.E., Zaremba, W., Luegebrune & K., Grunert, E., 1983. Untersuchungen über die Kolostrumaufnahme und die Immunoglobulinabsorption bei Kälbern mit und ohne Geburtsazidose. (Colostrum intake and immunoglobulin absorption of normal calves and those born with acidosis.) *Berliner Münchener Tierärztliche Wochenschrift 96*, 109–113 (In German).
Ekesbo, I., 1966. Disease incidence in tied and loose housed dairy cattle and causes of this incidence variation with particular reference to the cowshed type. *Acta Agriculturae Scandinavica, supplement No. 15*.
Ekesbo, I., 1973. Animal health, behaviour and disease prevention in different environments in modern Swedish animal husbandry. *Veterinary Record 93*, 36–39.
Ekesbo, I., 1974. Swedish studies of the impact of the environment on farm animals. *British Veterinary Journal 130*, 92–93.
Ekesbo, I., 1978. Intensive husbandry methods as a contribution to stress and disease of farm livestock. *Proceedings of the 1st World Congress on Ethology*, 23–27 October, Madrid, Spain, 93–97.
Ekesbo, I., 1988. Animal health implications as a result of future livestock and husbandry developments. *Applied Animal Behaviour Science 20*, 95–104.
Ekesbo, I., 2003. Kompendium i husdjurshygien. (Compendium of Animal Hygiene.) *Department of Animal Environment and Health, Swedish University of Agricultural Science*, Skara, Sweden. ISBN: 91-576-6289-4 (In Swedish).
Ekesbo, I., & Vilson, B., 1978. Comparison of different environmental factors on the incidence of mastitis. *Annual Meeting of the European Association for Animal Production*, 5–7 June, Stockholm, Sweden.
Elvander, M., 1996. A study of bovine respiratory syncytial virus infections in Swedish cattle. *Doctoral thesis, Swedish University of Agricultural Sciences*, Uppsala, Sweden.
Elvander, M., Baule, C., Persson, M., Egyed, I., Ballagí-Pordany, A., Belák, S. & Alenius, S., 1998. An experimental study of a concurrent primary infection with bovine respiratory syncytial virus (BRSV) and bovine viral diarrhoea virus (BVDV) in calves. *Acta Veterinaria Scandinavica 39*, 251–264.

Empel, W., Grabowski, R., Brzozowski, P., Kozanecki, M., Kurek, A. & Markiewicz-Grabowska, H., 1993. The effect of morbidity in calves on the results of the heifer rearing. *Annals of Warsaw Agricultural University – SGGW – Animal Science 28*, 61–66.

Ersbøll, A.K., Rugbjerg, H. & Stryhn, H., 2001. Increased mortality among calves in Danish cattle herds during bovine virus diarrhoea infection. *XIth International Conference on Production Diseases in Farm Animals*, 12–16 August, Fredriksberg, Denmark, 77–78.

Fallon, R.J., 1979. The effect of different methods of feeding colostrum on calf blood serum immunoglobulin levels. *Current Topics in Veterinary Medicine 4*, 507–517.

Fenner, F., Bachmann, P.A., Gibbs, E.P.J., Murphy, F.A., Studdert, M.J. & White, D.O., 1987. *Veterinary Virology*. Academic Press, Inc., San Diego, CA, USA.

Fiems, L.O., Boucqué, C.V., Cottyn, B.G. & Buysse, F.X., 1982. Effect of feeding techniques and age at weaning on the performances of bucket-fed and suckling-reared calves. In: Signoret, J.P. (Ed.) *Welfare and Husbandry of Calves, Current Topics in Veterinary Medicine and Animal Science 19*, 149–167.

Flower, F.C., & Weary, D.M., 2001. Effects of early separation on the dairy cow and calf: 2. Separation at 1 day and 2 weeks after birth. *Applied Animal Behaviour Science 70*, 275–284.

Foldager, J., & Krohn, C.C., 1991. Kviekalven; Opdraettet på meget høj eller normal fodringsintensitet fra fødsel til 6–10 ugers alderen og deres senere maelkeproduktion. (Heifer calves raised on very high or normal feeding intensity from birth to 6–10 weeks of age and their later milk production.) *Meddelse No. 794, Statens Husdyrbrugførsøg*, Foulum, Denmark (In Danish).

Fourichon, C., Beaudeau, F. & Seegers, H., 1997. Critical points related to housing and management in control programmes for calf morbidity and mortality in French dairy herds, *Proceedings of the IXth International Congress on Animal Hygiene*, 17–21 August, Helsinki, Finland, 32–35.

Frankena, K., van Kneulen, K.A.S., Noordhuizen, J.P., Noordhuizen-Stassen, E.N., Gundelach, J., de Jong, D.J. & Saedt, I., 1993. A cross-sectional study of prevalence and risk factors of dermatitis interdigitalis in female dairy calves in the Netherlands. *Preventive Veterinary Medicine 17*, 133–144.

Fraser, C.M., Mays, A., Amstutz, H.E., Archibald, J., Armour, J., Blood, D.C., Newberne, P.M., Snoeyenbos, G.H. & Huebner, R.A., 1986. *The Merck Veterinary Manual*. 6th ed. Merck & Co., Inc., Rahway, NJ, USA.

Ganaba, R., Bigras-Poulin, M., Belanger, D. & Couture, Y., 1995. Description of cow-calf productivity in Northwestern Quebec and path models for calf mortality and growth. *Preventive Veterinary Medicine 24*, 31–42.

Gardner, I.A., Hird, D.W., Utterback, W.W., Danaye-Elmi, C., Heron, B.R., Christiansen, K. & Sischo, W.M., 1990. Mortality, morbidity, case-fatality and culling rates for California dairy cattle as evaluated by the national animal health monitoring system, 1986–87. *Preventive Veterinary Medicine 8*, 157–170.

Garthwaite, B.D., Drackley, J.K., McCoy, G.C. & Jaster, E.H., 1994. Whole milk and oral rehydration solution for calves with diarrhoea of spontaneous origin. *Journal of Dairy Science 77*, 835–843.

Gill, G.S., & Allaire, F.R., 1976. Relationship of age at first calving, days open, days dry, and herdlife to a profit function for dairy cattle. *Journal of Dairy Science 59*, 1131–1138.

Gitau, G.K., McDermott, J.J., Adams, J.E., Lissemore, K.D. & Waltner-Toews, D., 1994. Factors influencing calf growth and daily weight gain on smallholder dairy farms in Kiambu District, Kenya. *Preventive Veterinary Medicine 21*, 179–190.

Glass, R.I., Kilgore, P.E., Holman, R.C., Jin, S., Smith, J.C., Woods, P.A., Clarke, M.J., Ho, M.S. & Gentsch, J.R., 1996. The epidemiology of rotavirus diarrhea in the United States: surveillance and estimates of disease burden. *Journal of Infectious Disease 174*, 5–11.

Goldstein, H., Browne, W. & Rasbash J., 2002. Multilevel modelling of medical data. *Statistics in Medicine 21*, 3219–3315.

Goodger, W.J. & Theodore, E.M., 1986. Calf management practices and health management decisions on large dairies. *Journal of Dairy Science 69*, 580–590.

Grau, F.H., 1988. *Campylobacter jejuni* and *Campylobacter hyointestinalis* in the intestinal tract and on the carcasses of calves and cattle. *Journal of Food Protection 51*, 857–861.
Gunn, G.J., & Stott, A.W., 1997. A comparison of economic losses due to calf enteritis and calf pneumonia in northern Scotland. *Proceedings of the VIIIth International Symposium of Veterinary Epidemiology and Economics*, 8–11 July, Paris, France, 10.06.1–10.06.3.
Hammond, D.M., Davis, L.R., & Bowman, G.W., 1944. Experimental infection with *Eimeria bovis* in calves. *American Journal of Veterinary Research 5*, 303–311.
Hannan, J., & Murphy, P.A., 1983. Comparative mortality and morbidity rates for cattle on slatted floors and in straw yards. Indicators relevant to farm animal welfare. Martinus Nijhoff Publishers, Den Haag, The Netherlands, 139–142.
Harry, E.G., 1978. Air pollution in farm buildings and methods of control: a review. *Avian Pathology 7*, 441–454.
Hartwig, N., & Kilmer, L., 1984. Heifer care from breeding to calving. *Dairy Herd Management 21*, 22–24.
Heffernan, H., & Schacke, L.M., 1976. Behaviour of early weaned calves. *Journal of Animal Science 54*, 209–210.
Heinrichs, A.J., 1993. Raising dairy replacements to meet the needs of the 21st century. *Journal of Dairy Science 76*, 3179–3187.
Heinrichs, A.J., Rogers, G.W. & Cooper, J.B., 1992. Predicting body weight and height in Holstein heifers using body measurements. *Journal of Dairy Science 75*, 3576–3581.
Hindhede, J., Sørensen, J.T., Jensen, M.B. & Krohn, C.C., 1996. Effect of space allowance, access to bedding and flock size in slatted floor systems on the production and health of dairy heifers. *Acta Agriculturae Scandinavica – Animal Science 46*, 46–53.
Hoffman, P.C., & Funk, D.A., 1992. Applied dynamics of dairy replacement growth and management. *Journal of Dairy Science 75*, 2504–2516.
Holliman, A., 2000. Overview of coccidiosis – recent observations. *Cattle Practice 8*, 83–88.
Hultgren, J., & Bergsten, C., 2001. Effects of rubber-slatted flooring systems on cleanliness and foot health in tied dairy cows. *Preventive Veterinary Medicine 52*, 75–89.
Jennings, A.R., & Glover, R.E., 1952. Enzootic pneumonia in calves. II. The experimental disease. *Journal of Comparative Pathology 62*, 6–22.
Jensen, M.B., 1999. Effects of confinement on rebounds of locomotor behaviour of calves and heifers, and the spatial preferences of calves. *Applied Animal Behaviour Science 62*, 43–56.
Kallo, O.J., Abdul-Ghani, Z.G. & Khalid, F.R., 1997. Incidence of joint infection in calves. *The Bovine Practitioner 31*, 1–3.
Kapil, S., & Basaraba, R.J., 1997. Infectious bovine rhinotracheitis, parainfluenza-3, and respiratory coronavirus. *Veterinary Clinics of North America: Food Animal Practice 13*, 455–469.
Kiorpes, A.L., Dubielzig, R.R. & Beck, K.A., 1988. Enzootic pneumonia in calves: clinical and morphological features. *Compendium on Continuing Education for Practicing Veterinarians 10*, 248–261.
Krogh, H.V., & Henriksen, S.-A., 1985. Bovine cryptosporidiosis in Denmark. II. *Cryptosporidia* associated with neonatal calf diarrhea. *Nordisk Veterinaermedicin 37*, 42–47.
Krohn, C.C., Foldager, J. & Mogensen, L., 1999. Long-term effect of colostrum feeding methods on behaviour in female dairy calves. *Acta Agriculturae Scandinavica – Animal Science 49*, 57–64.
Kruse, V., 1970. Absorption of immunoglobulin from colostrum in newborn calves. *Animal Production 12*, 627–638.
Kung, L., Jr., de Marco, S., Siebenson, L.N., Joyner, H., Haenlein, G.F.W. & Morris, R.M., 1997. An evaluation of two management systems for rearing calves fed milk replacers. *Journal of Dairy Science 80*, 2529–2533.
Lampe, K.G., Schwartz, A. & Seyfert, A., 1911. *Veterinären. Boken om våra husdjur. Illustrerad djurläkekonst. (The Veterinarian. A Book about our Farm Animals. Illustrated Animal Medicine.)* Nordiska Bokförlaget, Stockholm, Sweden (In Swedish).

Larsen, L.E., 2000. Bovine respiratory syncytial virus (BRSV): a review. *Acta Veterinaria Scandinavica 41*, 1–24.
Larsson, B., Niskanen, R. & Alenius, S., 1994. Natural infection with bovine virus diarrhoea virus in a dairy herd: a spectrum of symptoms including early reproductive failure and retained placenta. *Animal Reproduction Science 36*, 37–48.
Liberg, P., 2000. Råmjölksutfodring – "En god start förlänger livet". (Colostrum feeding – "A good start prolongs life".) *Proceedings of the Svenskt Veterinärmöte*, 9–10 November, Uppsala, Sweden, 133–139 (In Swedish).
Liberg, P. & Carlsson, J., 1998. Colostrum in Swedish dairy cows: quality and effects on passive immunity in the calves. *Proceedings of the Xth International Congress on Production Disease in Farm Animals*. 24–28 August, Utrecht, The Netherlands, 98.
Lidfors, L., 1992. Behaviour of bull calves in two different housing systems: deep litter in an uninsulated building versus slatted floor in an uninsulated building. *Report No. 30, Licenciate thesis, Department of Animal Hygiene, Swedish University of Agricultural Sciences*, Skara, Sweden, ISBN: 91-576-4489-6.
Lidfors, L.M., 1996. Behavioural effects of separating the dairy calf immediately or 4 days post-partum. *Applied Animal Behaviour Science 49*, 269–283.
Lin, C.Y., McAlliater, A.J., Batra, T.R. & Lee, A.J., 1988. Effects of early and late breeding of heifers on multiple lactation performance of dairy cows. *Journal of Dairy Science 71*, 2735–2743.
Linman, M., 1920. *Kortfattad lärobok i husdjursskötsel, utarbetad för fortsättningsskolor. Del II. Husdjurens avel, raser, utfodring och vård. (Short Textbook in Farm Animal Mangement for Secondary Schools. Part II. Farm Animal Breeding, Breeds, Feeding and Care.)* A.-B. Magn. Bergvalls Förlag, Stockholm, Sweden (In Swedish).
Logan, E.F., McBeath, D.G. & Lowman, B.G., 1974. Quantitative studies on serum immunoglobulin levels in suckled calves from birth to five weeks. *Veterinary Record 94*, 367–370.
Logan, E.F., Meneely, D.J. & Lindsay, A., 1981. Colostrum and serum immunoglobulin levels in Jersey cattle. *British Veterinary Journal 137*, 279–282.
Long, P.L., 1990. *Coccidiosis of Man and Domestic Animals*. CRC Press, FL, USA.
Lu, C.P., Yao, H.C. & Eichhorn, W., 1991. Coronavirus as an agent of neonatal calf diarrhea in a Chinese dairy cattle farm. *Journal of Veterinary Medicine 38*, 473–476.
Maatje, K., Verhoeff, J., Kremer, W.D.J., Cruijsen, A.L.M. & van den Ingh, T.S.G.A.M, 1993. Automated feeding of milk replacer and health control of group-housed veal calves. *Veterinary Record 133*, 266–270.
Manske, T., Hultgren, J. & Bergsten, C., 2002. The effect of claw trimming on the hoof health of Swedish dairy cattle. *Preventive Veterinary Medicine 54*, 113–129.
McDermott, J.J., & Schukken, Y.H., 1994. A review of methods used to adjust for cluster effects in explanatory epidemiological studies of animal populations. *Preventive Veterinary Medicine 18*, 155–173.
McDermott, J.J., Schukken, Y.H. & Shoukri M.M., 1994. Study design and analytic methods for data collected from clusters of animals. *Preventive Veterinary Medicine 18*, 175–191.
McGuirk, S.M., 1998. New approach to electrolyte therapy. *Cattle Practice 6*, 67–69.
Michanek, P., & Ventorp, M., 1989. Intestinal transmission of macromolecules in newborn dairy calves of different ages at first feeding. *Research of Veterinary Science 46*, 375–379.
Michanek, P., & Ventorp, M., 1993. Passive immunization of new-born dairy calves on three farms with different housing systems. *Swedish Journal Agricultural Research 23*, 37–43.
Morin, M., Lariviere, S., Lallier, R., Begin, M., Roy, R., Ethier, R. & Acres, S.D., 1978. Neonatal calf diarrhea: pathology and microbiology of spontaneous cases in dairy herds and incidence of the enteropathogens implicated as etiological agents. *Proceedings of the IInd International Symposium on Neonatal Diarrhea*, 3–5 October, Saskatchewan, Canada, 368–369.
Mosier, D.A., 1997. Bacterial pneumonia. *Veterinary Clinics of North America: Food Animal Practice 13*, 483–493.

Mourits, M.C.M., van der Fels-Klerx, H.J., Huirne, R.B.M. & Huyben, M.W.C., 2000. Dairy-heifer management in the Netherlands. *Preventive Veterinary Medicine 46*, 197–208.
Mäntysaari, P., Ingvartsen, K.L., Toivonen, V. & Sejrsen, K., 1995. The effects of feeding level and nitrogen source of the diet on mammary development and plasma-hormone concentrations of pre-pubertal heifers. *Acta Agriculturae Scandinavica – Animal Science 45*, 236–244.
Niilo, L., 1970. Experimental winter coccidiosis in sheltered and unsheltered calves. *Canadian Journal of Comparative Medicine 34*, 20–25.
Nordgren, P., 1997. Inkalvningsålderns betydelse för lönsamheten i mjölkbesättningen. (The Importance of the Age at First Calving for the Profitability of the Dairy Farm.) *Svensk Mjölk*, Hållsta, Sweden (In Swedish).
Norrman, E., 1990. Kviguppfödning och kvigmastit. (Raising of Heifers, and Heifer Mastitis.) *Report No. 67, Research Information Center, Swedish University of Agricultural Sciences*, Uppsala, Sweden , ISBN: 91-576-4109-9 (In Swedish).
Odde, K.G., 1988. Survival of the newborn calf. *Veterinary Clinics of North America: Food Animal Practice 4*, 501–508.
O'Donoghue, P.J., 1995. *Cryptosporidium* and cryptosporidiosis in man and animals. *International Journal of Parasitology 25*, 139–195.
Olsson, S.-O., Viring, S., Emanuelsson, U. & Jacobsson, S.-O., 1993. Calf diseases and mortality in Swedish dairy herds. *Acta Veterinaria Scandinavica 34*, 263–269.
Ortman, K., & Svensson, C., 2004. Use of antimicrobial drugs in Swedish dairy calves and replacement heifers. *Veterinary Record 154*, 136–140.
Pellerin, C., van den Hurk, J., Lecomte, J. & Tussen, P., 1994. Identification of a new group of bovine viral diarrhea virus strains associated with severe outbreaks and high mortality. *Virology 203*, 260–268.
Perez, E., Noordhuizen, J.P.T.M., van Wuijkhuise, L.A. & Stassen, E.N., 1990. Management factors related to calf morbidity and mortality rates. *Livestock Production Science 25*, 79–93.
Petitclerc, D., Dumolin, P., Ringvet, H., Matte, J. & Girard, C., 1999. Plane of nutrition and folic acid supplementation between birth and four months of age on mammary development of dairy heifers. *Canadian Journal of Animal Science 79*, 227–234.
Petrie, L.M., 1984. Maximising the absorption of colostral immunoglobulins in the newborn dairy calf. *Veterinary Record 114*, 157–163.
Phillippo, M., Arthur, J.R., Price, J. & Halliday, G.J., 1987. The effect of selenium, housing and management on the incidence of pneumonia in housed calves. *Veterinary Record 121*, 509–512.
Phillips, R.W., 1985. Fluid therapy for diarrheic calves. What, how, and how much. *Veterinary Clinics of North America: Food Animal Practice 1*, 541–562.
Plath, U., 1999. Beurteilung verschiedener Tränketechniken und Betreuungsmassnahmen hinsichtlich ihrer Auswirkungen auf die oralen Aktivitäten, den Gesundheitszustand und die Mastleitung über zwei bis acht Wochen alter Mastkälber in Gruppenhaltung. (Assessment of drinking equipment and group housing for calves aged 2–8 weeks, as reflected in oral activity, health and growth.) *Dissertation, Institut für Tierhygiene und Tierschutz der Tierärtzlichen Hochschule*, Hannover, Germany (In German).
Potgieter, L.N.D., McCracken, M.D., Hopkins, F.M. & Walker, R.D., 1984. Effect of bovine viral diarrhea virus infection on the distribution of infectious bovine rhinotracheitis virus in calves. *Journal of American Veterinary Research 45*, 687–690.
Quigley, J.D., Martin, K.R., Bemis, D.A., Potgieter, L.N.D., Reinemeyer, C.R., Rohrbach, B.W., Dowlen, H.H. & Lamar, K.C., 1995. Effects of housing and colostrum feeding on serum immunoglobulins, growth, and fecal scores of Jersey calves. *Journal of Dairy Science 78*, 893–901.
Radcliff, R.P., Vandehaar, M.J., Skidmore, A.L., Chapin, L.T., Radke, B.R., Lloyd, J.W., Stanisiewski, E.P. & Tucker, H.A., 1997. Effects of diet and bovine somatropin on heifer growth and mammary development. *Journal of Dairy Science 80*, 1996–2003.

Radostits, O.M., Gay, C.C., Blood, D.C. & Hinchcliff, K.W., 1999. *Veterinary Medicine. A textbook of the diseases of cattle, sheep, pigs, goats and horses*. 9th ed.. W.B. Saunders Company Ltd, London, UK, chapters 3, 6, 10 and 16–20.

Rajala, P., & Castrén, H., 1995. Serum immunoglobulin concentrations and health of dairy calves in two management systems from birth to 12 weeks of age. *Journal of Dairy Science 78*, 2737–2744.

Redbo, I., 1990. Changes in duration and frequency of stereotypies and their adjoining behaviours in heifers, before, during and after the grazing period. *Applied Animal Behaviour Science 26*, 57–67.

Reynolds, D.J., Morgan, J.H., Chanter, N., Jones, P.W., Bridger, J.C., Debney, T.G. & Bunch, K.J., 1986. Microbiology of calf diarrhoea in southern Britain. *Veterinary Record 119*, 34–39.

Robison, J.D., Stott, G.H. & DeNise, S.K., 1988. Effects of passive immunity on growth and survival in dairy heifer. *Journal of Dairy Science 71*, 1283–1287.

Rood, J.I., & Cole, S.T., 1991. Molecular genetics and pathogenesis of Clostridium perfringens. *Microbiological Reviews 55*, 621–628.

Roy, J.H.B., 1980. Symposium: disease prevention in calves. Factors affecting susceptibility of calves to disease. *Journal of Dairy Science 63*, 650–664.

Roy, J.H.B., 1990. *The Calf. Volume 1, Management of Health*. Butterworths, London, UK.

Saif, L.J., & Theil, K.W., 1990. *Viral Diarrhea in Man and Animals*. CRC Press, FL, USA

Sejrsen, K., Huber, J.T., Tucker, H.A. & Alckers, R.M., 1982. Influence of nutrition on mammary development in pre- and postnatal heifers. *Journal of Dairy Science 65*, 793–800.

Shearer, J., Mohammed, H.O., Brenneman, J.S. & Tran, T.Q., 1992. Factors associated with concentrations of immunoglobulins in colostrum at the first milking post-calving. *Preventive Veterinary Medicine 14*, 143–154.

Simensen, E., 1981. Climatic conditions and their relation to housing factors in Norwegian dairy barns with special reference to young stock. *Acta Agriculturae Scandinavica 31*, 267–272.

Simensen, E., & Norheim, K., 1983a. An epidemiological study of calf health and performance in Norwegian dairy herds. III. Morbidity and performance: literature review, characteristics. *Acta Agriculturae Scandinavica 33*, 57–64.

Simensen, E., & Norheim, K., 1983b. An epidemiological study of calf health and performance in Norwegian dairy herds. IV. Factors affecting morbidity and performance. *Acta Agriculturae Scandinavica 33*, 65–74.

Sivula, N.J., Ames, T.R., Marsh, W.E. & Werdin, R.E., 1996a. Descriptive epidemiology of morbidity and mortality in Minnesota heifer calves. *Preventive Veterinary Medicine 27*, 155–171.

Sivula, N.J., Ames, T.R., Marsh, W.E. & Werdin, R.E., 1996b. Management practices and risk factors for morbidity and mortality in Minnesota heifer calves. *Preventive Veterinary Medicine 27*, 173–182.

Snodgrass, D.R., Terzelo, H.R., Sherwood, D., Campbell, I., Menzies, J.D. & Synge, B.A., 1986. Aetiology of diarrhoea in young calves. *Veterinary Record 119*, 31–34.

Stenebo, H., 1995. Har uppfödningen från kalv till ko någon betydelse för 1:a-kalvarens hälsa? (Does the raising from calf to cow affect the health status of the first lactating cow?) *Degree project, Swedish University of Agricultural Sciences*, Uppsala, Sweden (In Swedish).

Sternberg, S., & Boqvist, S., 2003. Vad är det för vits med svensk salmonellakontroll? (What's the point of the Swedish Salmonella programme?) *Svensk Veterinärtidning 55*, 6, 6–10 (In Swedish).

Stockdale, P.H.G., 1977. The pathogenesis of lesions produced by the Eimeria zuernii in calves. *Canadian Journal of Comparative Medicine 41*, 338–344.

Stott, G.H., Marx, D.B., Menefee, B.E. & Nightingale, G.T., 1979a. Colostral immunoglobulin transfer in calves. III. Amount of absorption. *Journal of Dairy Science 62*, 1902–1907.

Stott, G.H., Marx, D.B., Menefee, B.E. & Nightingale, G.T., 1979b. Colostral immunoglobulin transfer in calves. IV. Effect of suckling. *Journal of Dairy Science 62*, 1908–1913.
Sørensen, J.T. & Foldager, J., 1991. Effect of breed and plane nutrition on the estimation of live weight by heart girth in dual purpose heifers. *Acta Agriculturae Scandinavica 41*, 161–169.
Taylor, M.A., & Catchpole, M., 1994. Coccidiosis of domestic ruminants. *Applied Parasitology 35*, 73–86.
Tegtmeier, C., Uttenthal, A.A., Friis, N.F., Jensen, N.E. & Jensen, H.E., 1996. Pathological and microbiological studies on pneumonic lungs from Danish calves. *Journal of Veterinary Medicine B 46*, 693–700.
Thomas, L.H., Wood, P.D.P. & Longland, J.M., 1978. The influence of disease on the performance of beef cattle. *British Veterinary Journal 34*, 152–161.
Tzipori, S., 1981. The aethiology and diagnosis of calf diarrhoea. *Veterinary Record 108*, 510–515.
Uga, S., Matsuo, J., Kono, E., Kimura, K., Inoue, M., Rai, S.K. & Ono, K., 2000. Prevalence of Cryptosporidium parvum infection and pattern of oocyst shedding in calves in Japan. *Veterinary Parasitology 94*, 27–32.
Urquhart, G.M., Armour, J., Duncan, J.L., Dunn, A.M. & Jennings, F.W., 1991. *Veterinary Parasitology*. Longman Scientific & Technical, Essex, UK.
van Amburgh, M.E., Galton, D.M., Bauman, D.E., Everett, R.W., Fox, D.G., Chase, L.E. & Erb, H.N., 1998. Effects of three prepubertal body growth rates on performance of Holstein heifers during first lactation. *Journal of Dairy Science 81*, 527–538.
van der Fels-Klerx, H.J., Horst, H.S. & Dijkhuizen, A.A., 2000. Risk factors for bovine respiratory disease in dairy youngstock in The Netherlands: the perception of experts. *Livestock Production Science 66*, 35–46.
van der Pohl, W.H.M, Brand, A., Kramps, J.A., Middel, W.G.J. & van Oirshot, J.T., 1993. Dynamics of bovine respiratory syncytial virus: a longitudinal epidemiological study in dairy herds. *Archives of Virology 133*, 309–321.
van Doenkersgoed, J., Ribble, C.S., Boyer, L.G. & Townsend, H.G.G., 1993. Epidemiological study of enzootic pneumonia in dairy calves in Saskatchewan. *Canadian Journal of Veterinary Research 57*, 247–254.
Veissier, I., Gesmeir, V., Le Neindre, P., Gautier, J.Y. & Bertrand, G., 1994. The effects of rearing in individual crates on subsequent social behaviour of veal calves. *Applied Animal Behaviour Science 41*, 199–210.
Ventorp, M., & Michanek, P., 1990. The importance of udder and teat conformation for teat seeking by the newborn calf. *Journal of Dairy Science 75*, 262–268.
Verhoeff, J., & van Nieuwstadt, A.P.K.M.I., 1984. BRS virus, PI3 virus, and BHV1 infections of young stock on self-contained dairy-farms: epidemiological and clinical findings. *Veterinary Record 114*, 288–293.
Vermunt, J.J., & Greenough, P.R., 1995. Lesions associated with subclinical laminitis of the claws of dairy calves in two management systems. *British Veterinary Journal 151*, 391–399.
Viring, S., Olsson, S.-O., Alenius, S., Emanuelsson, U., Jacobsson, S.-O., Larsson, B., Linde, N. & Uggla, A., 1993. Studies of enteric pathogens and gamma-globulin levels of neonatal calves in Sweden. *Acta Veterinaria Scandinavica 34*, 263–269.
Virtala, A.-M., Mechor, G.D., Gröhn, Y.T. & Erb, H.N., 1996a. Morbidity from nonrespiratory diseases and mortality in dairy heifers during the first three months of life. *Journal of the American Veterinary Medicine Association 208*, 2043–2046.
Virtala, A.-M.K., Mechor, G.D., Gröhn, Y.T. & Erb, H.N., 1996b. The effect of calfhood diseases on growth of female dairy calves during the first three months of life in New York State. *Journal of Dairy Science 79*, 1040–1049.
Virtala, A.-M.K., Gröhn, Y.T., Mechor, G.D. & Erb, H.N., 1999. The effect of maternally derived immunoglobulin G on the risk of respiratory diseases in heifers during the first 3 months of life. *Preventive Veterinary Medicine 39*, 25–37.

Virtala, A.-M.K., Mechor, G.D., Gröhn, Y.T., Erb, H.N. & Dubovi, E.J., 1996. Epidemiologic and pathological characteristics of respiratory tract disease in dairy heifers during the first three months of life. *Preventive Veterinary Medicine 12*, 2035–2042.
Wahlström, H., 2001. Zoonoses in Sweden up to and including 1999. *National Veterinary Institute*, Uppsala, Sweden.
Waltner-Toews, D., Martin, S.W. & Meek, A.H., 1986a. An epidemiological study of selected pathogens on Holstein dairy farms in southwestern Ontario. *Canadian Journal of Research 50*, 307–313.
Waltner-Toews, D., Martin, S.W. & Meek, A.H., 1986b. Dairy calf management, morbidity and mortality in Ontario Holstein herds. III. Association of management with morbidity. *Preventive Veterinary Medicine 4*, 137–158.
Waltner-Toews, D., Martin, S.W. & Meek, A.H., 1986c. The effect of early calfhood health status on survivorship and age at first calving. *Canadian Journal of Research 50*, 314–317.
Waltner-Toews, D., Martin, S.W., Meek, A.H. & McMillan I., 1986. Dairy calf management, morbidity and mortality in Ontario Holstein herds. I. The data. *Preventive Veterinary Medicine 4*, 103–124.
Warner, D.P., & Bryner, J.H., 1984. *Campylobacter jejuni* and *Campylobacter coli* inoculation of neonatal calves. *American Journal of Veterinary Research 45*, 1822–1824.
Warnick, V.D., Arave, C.W. & Mickelsen, C.H., 1977. Effects of group, individual and isolated rearing of calves on weight gain and behaviour. *Journal of Dairy Science 60*, 947–953.
Warnick, V.D., Erb, H.N. & White, M.E., 1995. Lack of association between calf morbidity and subsequent first lactation milk production in 25 New York Holstein herds. *Journal of Dairy Science 78*, 2819–2830.
Warnick, V.D., Erb, H.N. & White, M.E., 1997. The relationship of calfhood morbidity with survival after calving in 25 New York Holstein herds. *Preventive Veterinary Medicine 31*, 263–273.
Wathes, C.M., Jones, C.D.R. & Webster, A.J.F., 1983. Ventilation, air hygiene and animal health. *Veterinary Record 113*, 554–559.
Webster, A.J.F., 2000. Effects of wet v. dry feeding and housing type on the pathogenesis of claw horn disruption in first-lactation dairy cattle. *Proceedings of the XIth International Symposium on Disorders of the Ruminant Digit & the IIIrd International Conference on Bovine Lameness*, 3–7 September, Parma, Italy, 290–294.
Webster, A.J.F., Saville, C., Church, B.M., Gnanasakhty, A. & Moss, R., 1985. The effect of different rearing systems on the development of calf behaviour. *British Veterinary Journal 141*, 249–264.
Wells, S.J., Garber, L.P. & Hill, G.W., 1996. Health status of preweaned dairy heifers in the United States. *Preventive Veterinary Medicine 29*, 185–199.
Widebeck, L., 1997. Chapters: Kalven. (The calf) and Rekryteringskvigan. (The replacement heifer.) In *Mjölkkor (Dairy cows)*, LTs Förlag, Stockholm, Sweden, pp. 64–86, 87–101 (In Swedish).
Wittum, T.E. & Perino, L.J., 1995. Passive immune status at postpartum hour 24 and long-term health and performance of calves. *American Journal of Veterinary Research 9*, 1149–1154.
Wittum, T.E., Salman, M.D., King, M.E., Mortimer, R.G., Odde, K.G. & Morris, D.L., 1994a. Individual animal and maternal risk factors for morbidity and mortality of neonatal beef calves in Colorado, USA. *Preventive Veterinary Medicine 19*, 1–13.
Wittum, T.E., Salman, M.D., King, M.E., Mortimer, R.G., Odde, K.G. & Morris, D.L., 1994b. The influence of neonatal health on weaning weight of Colorado, USA, beef calves. *Preventive Veterinary Medicine 19*, 15–25.
Wray, C., & Roeder, P.L., 1987. Effect of bovine virus diarrhoea-mucosal disease virus infection on salmonella infection in calves. *Research in Veterinary Science 42*, 213–218.
Wray, C., & Thomlinson, J.R., 1975. Factors influencing occurrence of colibacillosis in calves. *Veterinary Record 96*, 52–56.

# Acknowledgements

The studies presented in this thesis were carried out at the Department of Animal Environment and Health, Sections of Animal Hygiene and Production Diseases, of the Swedish University of Agricultural Sciences, Skara, Sweden.

The studies were made possible by grants from the Swedish Farmers' Foundation for Agricultural Research, the Swedish Council for Forestry and Agricultural Research, the Skövde and Växjö Djurskyddsföreningar, Stiftelsen Skaraborgs Nötkreaturförsäkringsbolagsfond, Agroväst, the AGRIA research fund, the Swedish Dairy Association and Bröderna Jonssons Forskningsfond. The studies have been associated with the MISTRA-financed FOOD21 project.

I would like to express my sincere gratitude to:

Professor Bo Algers, former Head of the Department of Animal Environment and Health and my former supervisor, for putting the facilities at the department at my disposal and for finding time in a busy schedule to listen to me on more than one occasion.

Associate Professor Lena Lidfors and Stefan Gunnarsson, former and present Heads of the Department of Animal Environment and Health, for putting the facilities at the department at my disposal. And to Lena again, for very pleasant company in Mexico!

Professor Catarina Svensson, Head of the Section of Production Diseases and my scientific supervisor, for sharing a long journey of both ups and downs, for your enthusiasm, ambitions and generosity, for teaching me a lot about scientific work and about life, and for your habit of lighting candles, your survival kit and the summer week in our "henhouse".

Per Liberg, my associate scientific supervisor, for teaching me about writing and living, for your capability of enjoying life, for your good sense of humour and for using that good sense when it was needed in "battle".

Professor Toni Oltenacu, my associate scientific supervisor, for your encouragement, your support and your warm personality and for being such a splendid maker of spaghetti. To both you and Raluca, for making my visits at Cornell University so pleasant.

Ulf Emanuelsson, Sven-Ove Olsson and Peter Strandberg, for all the valuable help in designing and analysing "Kvigprojektet".

Jan Nilsson, for your incredible patience with me and my minor and major computer problems and for guiding me through the very terrifying world of using SAS for editing data.

Jan Hultgren, Daniel Maizon and Hector Castillio, for invaluable and necessary help with statistical analyses. Without your help I would still be trying to figure out which is the right side up on a SAS or MLwiN printout. And again, to Daniel and also, to Emiliano Raffrenato, my office room-mate at Cornell, for filling my visits to Cornell with laughter.

Gunilla Jacobsson, for all the hours of transforming letters and numbers, that were hard to read, from sometimes very dirty papers that smelled of cow, into neat and organised data.

Carina Johansson and Annikki Turtinen, for help with the many tiny numbers in a very extensive survey. And to Carina again, for all the help with other practical details over the years.

Jonica Östlund, Lotta Andersson and the staff at Skara Semin, for all the help with collecting data and for their different ways (!) of encouraging the farmers to continue with "Kvigprojektet".

Beata Akersten and Britte Lindegren at the SLU library in Skara, for your help in finding references in an effective manner and for being so cheerful while doing it.

Professor Emeritus Ingvar Ekesbo, for your quick response to my need for references, and for the nice "historical" summary.

To all the other employees at the department, for making it a pleasant place even on a Monday morning and especially to Gudrun Norrman and Ulla Wass, for help with practical details and patience with me and my non-existent administrative skills.

All other PhD students and Postdocs, for sharing the journey with me. You have all been wonderful company. Some of you deserve special mention: thanks to Anna L, Anette, Christina, Maria and Margret, for support and encouragement; Karin and Tina, for caring in a stressful situation; Thomas, for wonderful philosophical discussions and statistical references; Jenny L, for being such a close and good friend and for memorable moments on horseback and in an outdoor bathtub; and Jenny & Jens, for being my generous landlords in Skara, for listening and caring, for good advice regarding everything important in life while walking the dogs and during cosy dinners, and for taking me and my family to Mexico. And to Jenny and Jenny again, for the surprise day!

The 122 farmers who gave of their time to let me examine their calves and to ask them lots and lots of questions.

The 3 081 heifer calves that let me examine them. Only on a few occasions did you step on my feet or kick me. I hope your participation in "Kvigprojektet" makes you feel proud!

David, my new boss, for giving me time to take the Pedagogic course and finish this thesis.

Pia, the very best of friends, for picking me up when I needed it most, for all the support, e-mails and phone calls through the years and for all the long discussions on any topic, and to Pia, Peo and Anna, for letting me be your basement ghost during my Uppsala visits.

My parents Gun and Jarl and my favourite brother Andreas, for support and encouragement through both good and bad times, and my mother, my father and Gunnela, Hans and Monica, for your excellent baby-sitting skills and for giving of your time and love to Magnina so that my guilty conscience with regard to her could stay within reasonable limits. And to my father and Gunnela, for running such an excellent dog and cat hotel.

… and most of all to Torbjörn and Magnina, for unequivocally being the best and most important part of my life. Torbjörn, you have been my best moral support, my largest financial sponsor and my favourite discussion partner. Without you this thesis would never have been completed. You are my best friend and the love of my life! Magnina, you are the sunshine of my life, my joy and my happiness and best of all, you are “mammas älkling”!