Netherlands Journal of Agricultural Science 50 (2002) 27-45

Effects on productivity and risk factors of Bovine Respiratory Disease in dairy heifers; a review for the Netherlands

H.J. VAN DER FELS-KLERX[1,3,*], S.W. MARTIN[2], M. NIELEN[1,4] AND R.B.M. HUIRNE[1]

[1] Farm Management Group, Wageningen University, Hollandseweg 1, NL-6706 KN Wageningen, The Netherlands
[2] Department of Population Medicine, Ontario Veterinary College, University of Guelph, Ontario, Canada
[3] Present address: National Institute for Public Health and the Environment (RIVM), P.O. Box 1, NL-3720 BA Bilthoven, The Netherlands
[4] Present address: Department of Farm Animal Health, Yalelaan 7, NL-3584 CL Utrecht
[*] Corresponding author (tel.: + 31-30-274-3929; fax: +31-30-274-4434: e-mail: ine.van.der.fels@rivm.nl)

Received: 27 April 2002; accepted: 13 December 2002

Abstract

This paper presents a literature review about the impact of Bovine Respiratory Disease (BRD) on the productivity of dairy heifers and about risk factors for the disease, as far as these are relevant to commercial dairy farming in the Netherlands. The review includes peer-reviewed publications over the period January 1980–June 2001 on field studies that quantified the variables of interest. The literature data show that BRD in dairy heifers increases the risk of mortality directly after the disease episode by up to 6 times and reduces growth during the first 6 months of life with up to 10 kg. In addition, the disease can increase mortality in later stages of the rearing period, and age and likelihood of dystocia at first calving. Other diseases in dairy heifers and herd size are clearly associated with the risk of BRD, and season and colostrum feeding management presumably affect this risk. Effects of other potential risk factors are less evident. In conclusion, although several associations were found, the data on the majority of the potential productivity effects and risk factors of BRD are ambiguous or incomplete. However, based on the literature data several recommendations for BRD prevention on Dutch dairy farms were made, which are discussed in this paper.

Introduction

Bovine Respiratory Disease (BRD) is an important health problem in the dairy cattle industry that mainly affects the younger animals (Radostits *et al.*, 1994; Quigley III *et al.*, 1996). BRD embraces all possible respiratory diseases in cattle, defined by abnormal clinical signs of the cattle's respiratory tract. The disease complex can be caused by one or more primary pathogens including respiratory viruses and *Mycoplasma* spp., often complicated by a secondary bacterial infection, or by bacteria alone. The infectious agents commonly cited include *Bovine Respiratory Syncytial Virus* (BRSV), *Parainfluenza-3 Virus* (PI_3-V), the Mycoplasmas *M. dispar* and *M. bovis*, and bacteria including *Pasteurella haemolytica*, *Pasteurella multocida* and *Haemophilus somnus* (Roy, 1990; Radostits *et al.*, 1994; Quigley III *et al.*, 1996).

Two types of BRD often distinguished in the Netherlands are (calf) pneumonia and BRD outbreaks (Van Der Fels-Klerx *et al.*, 2002) (see Appendix 1 for the definitions). Although infectious agents are primarily responsible for the clinical symptoms, several predisposing factors related to the animal or its environment markedly increase the likelihood and severity of the symptoms, i.e. the disease is multifactorial (Roy, 1990; Radostits *et al.*, 1994; Quigley III *et al.*, 1996). The severity of BRD can range from subclinical, through mild clinical to an acute fatal form. Symptoms vary and can include fever, nasal or serous discharge, coughing, increased respiration rate, decreased appetite, and sometimes mild diarrhoea (Roy, 1990; Radostits *et al.*, 1994). Farmers and veterinarians usually diagnose BRD and treat affected cattle on account of these symptoms rather than on specific etiology.

BRD can severely reduce the lifetime productivity of the affected cattle. Effects on the productivity ('productivity effects') associated with BRD in dairy heifers may include increased mortality, increased culling, reduced growth, reduced fertility, increased age at first calving, and reduced milk production. The losses associated with these productivity effects together with treatment expenditures contribute to the economic losses due to BRD. Field experiences indicate that on individual dairy farms in the Netherlands the economic losses due to BRD can be high, but an accurate estimate is not available. Producer-estimates from the US revealed that the on-farm losses of BRD averaged US$ 9.08 per cow-year in Ohio (Miller & Dorn, 1990), and US$ 14.71 per calf-year for pre-weaning heifers and US$ 1.95 per heifer-year for post-weaning heifers in Michigan (Kaneene & Hurd, 1990). These figures do not include losses due to chronic and long-term effects.

Because of variation in management among Dutch farms (Mourits *et al.*, 2000) and the multifactorial causality of BRD, the on-farm incidence of the disease and the associated economic losses can be reduced by improved farm management. To make economically sound decisions about the prevention of BRD, dairy farmers need to have more insight into the on-farm economic losses caused by the disease as well as the cost-effectiveness of various prevention measures. To obtain this quantitative economic insight, a better knowledge of the underlying variables, including the productivity effects and the risk factors of BRD in dairy heifers, is necessary.

This paper presents a literature review aimed at obtaining qualitative and quantitative information about the impact of BRD on the productivity of dairy heifers and about managerial risk factors of the disease that are relevant to the commercial dairy farming system in the Netherlands or to comparable heifer-raising conditions. The information obtained was to be used as a basis for an evaluation of the economic losses due to BRD and the cost-effectiveness of prevention of the disease on Dutch dairy farms.

Material and methods

The literature search made use of the computer programme WinSPIRS version 2.0 and the databases CAB Abstracts, Biological Abstracts® and CurrentContents Search®. These databases were found to be the most useful for the subject of the current review, applying the Gale Directory of Databases (Nagel, 2002). CAB Abstracts and Biological Abstracts® are the two most important and most complete databases on this topic, whereas CurrentContents Search® includes recent publications on nearly all sciences. Only peer-reviewed English-, German- and French-language publications between January 1980 and June 2001 were included that presented studies fulfilling the following criteria: (1) quantification of productivity effects and/or risk factors of BRD not caused by lungworm in dairy heifers, (2) performed in the field (not based on experiments), and (3) relevant for commercial dairy farms in the Netherlands. So only research was included that had been carried out on commercial or experimental farms in the Netherlands or elsewhere under conditions that were comparable with respect to climate, heifer-raising system, production level, and genetics. Technical reports, PhD theses, and proceedings and abstracts of conference papers were not included. Results from the included studies were restricted to data that had been statistically tested for their association with BRD and found significant at the 5% level.

Results

The results of the literature review are summarized in Table 1 for the productivity effects, and in Table 2 for the risk factors (restricted to two or more independent estimates). Background information on the epidemiological field studies cited is presented in Appendix 2.

Productivity effects

Mortality

Curtis *et al.* (1988a) reported that heifers with BRD before 90 days of age were at a 6.5 times higher risk of dying in this period than their non-affected herd mates, but others could not confirm this association (Perez *et al.*, 1990; Donovan *et al.*, 1998a). At herd level, the risk of mortality before 90 days of age increased with higher incidences of BRD in this period (Curtis *et al.*, 1993). Consistently, farms with above-median treatment days per heifer for pneumonia were 2.3 times more likely to also have above-median mortality rates compared with farms with below-median treatment days per heifer (Waltner-Toews *et al.*, 1986a).

Growth

In three studies it was shown that BRD reduced growth (Van Donkersgoed *et al.*, 1993; Virtala *et al.*, 1996a; Donovan *et al.*, 1998b). Pneumonia before the age of three months reduced weight gain during this period by 0.8 kg per week of the dis-

Table 1. Productivity effects of Bovine Respiratory Disease (BRD) in dairy heifers found statistically significant ($P < 0.05$) in epidemiological field studies.

Productivity effect	Association[1]	Level of analysis	Remarks	Reference
Mortality < 90 days	RR = 6.5	Calf		Curtis *et al.* (1988a)
Mortality < 90 days	OR = 12	Herd	Arcsin(BRD < 90 days)$^{0.5}$	Curtis *et al.* (1993)
Above-median mortality	OR = 2.3	Herd	Above-median treatment days/calf	Waltner-Toews *et al.* (1986a)
Weight gain < 3 months	–0.8 kg/treatment week	Calf		Virtala *et al.* (1996a)
Weight gain 0–6 months	–10.5 g day^{-1}/ treatment day	Calf		Donovan *et al.* (1998b)
Weight gain 6–14 months	–2.3 g day^{-1}/ treatment day	Calf		Donovan *et al.* (1998b)
Girth growth in 1st month	–0.04 cm day^{-1}	Calf	Farmer-diagnosed	Van Donkersgoed *et.al.* (1993)
	–0.05 cm day^{-1}	Calf	Veterinarian-diagnosed	
Mortality 90–900 days	OR = 2.4	Calf		Waltner-Toews *et al.* (1986b)
Likelihood first calving	HR = 0.5	Calf		Correa *et al.* (1988) Warnick *et al.* (1994)
Age at first calving	+3 months	Calf		Warnick *et al.* (1994)
Dystocia at first calving	OR = 2.4	Calf		Warnick *et al.* (1994)

[1] Unless stated otherwise, associations refer to BRD as defined in the particular study (see Appendices 1 and 2).

ease, which – given a mean duration of four weeks – resulted in a total weight reduction of 3.2 kg (Virtala *et al.*, 1996a). Heifers that had pneumonia between birth and six months of age had a reduced weight gain during this period of 10.6 kg on average. In addition, early pneumonia had a statistically significant, but marginal, harmful effect on weight gain during the period 6–14 months of 3.1 kg (Donovan *et al.*, 1998b). As 40% of the heifers left the herd before the age of six months because of the effect of chronic BRD on growth (selective loss of follow-up), the real impact of the disease on weight gain was likely to be higher (Donovan *et al.*, 1998b). From the studies referred to it is not clear whether or not growth reduction due to BRD is compensated for in later stages of the rearing period.

Mortality and culling up to first calving

Heifers that had been treated for pneumonia during the first three months of life were 2.4 times more likely to die between 90 and 900 days of age than heifers that had not been treated, but BRD did not significantly alter the risk of being culled for beef or sold for dairy (Waltner-Toews *et al.*, 1986b). In accordance with this observation Curtis *et al.* (1989) reported that BRD before the age of 90 days had no effect on the likelihood of being sold thereafter. The effect of early BRD on the likelihood of dying after 90 days was not found statistically significant (Curtis *et al.*, 1989), which is in contrast with the data of Waltner-Toews *et al.* (1986b). In the latter study only more severely diseased heifers were treated and recorded as a morbidity event, whereas in the study of Curtis *et al.* (1989) BRD need not have been treated.

Reproduction up to first calving

Heifers that had suffered BRD before the age of 90 days were half as likely to calve (at any particular age) as heifers without this illness (Correa *et al.*, 1988; Warnick *et al.*, 1994). On the other hand, Waltner-Toews *et al.* (1986b) found no difference in the percentage calving before the age of 900 days between heifers with and heifers without calf pneumonia.

The median age at first calving of heifers that had suffered BRD before the age of 90 days was delayed by three months compared with non-affected herd mates (Warnick *et al.*, 1994). Two other studies reported no difference in age at first calving between heifers that suffered early pneumonia and their non-diseased herd mates (Britney *et al.*, 1984; Waltner-Toews *et al.*, 1986b). The effect of BRD on the incidence of fertility disorders during the rearing period, such as return to oestrus, was not investigated.

Performance at or after first calving

At first calving, heifers that had suffered from BRD before the age of 90 days were 2.4 times more likely to have dystocia (a difficult calving) than non-diseased heifers (Warnick *et al.*, 1994). According to these authors, the detrimental association of BRD with dystocia and with age at first calving could be due to a negative effect of early BRD on growth, but this was not measured in the study (Warnick *et al.*, 1994). Both calving interval and the proportion of live-born calves per lactation for heifers that had suffered calfhood BRD were not different from their non-BRD herd mates (Britney *et al.*, 1984).

The effect of BRD before the age of 90 days on longevity after calving as indicated by milking herd life, was found to be statistically non-significant (Warnick *et al.*, 1997). In accordance with these results, Britney *et al.* (1984) reported that the survival distribution from birth to over 96 months of age for heifers that had suffered BRD was not different from their non-diseased herd mates. The latter study also found no difference in milk production on a lactation basis between the cohort of heifers that had suffered BRD and their non-affected controls. Accordingly, data from heifers that had survived calfhood BRD and remained in the herd long enough to have milk production recorded, showed that the disease had no adverse effect on first lactation milk production (Warnick *et al.*, 1995). However, in this study the percentage heifers that survived and were kept as herd replacements tended to be lower for heifers affected by calfhood BRD (Warnick *et al.*, 1995).

In summary, BRD in dairy heifers increases the risk of mortality directly after the disease episode by up to 6 times and reduces growth during the first 6 months of life with up to 10 kg. Whether the short-term effects on growth extend into the later breeding and production periods is not clear. BRD does not seem to significantly affect the risk of being culled or sold during the rearing period. Results on effects of the disease on mortality in later stages of the rearing period and on age at first calv-

Table 2. Managerial risk factors of Bovine Respiratory Disease (BRD) in dairy heifers found statistically significant ($P < 0.05$; ≥ 2 independent estimates) in epidemiological field studies.

Risk factor	Risk factor levels	Association[1]	Level of analysis	Remarks	Reference
Season of birth	Winter vs. summer	Negative	Calf	Age at first treatment	Waltner-Toews *et al.* (1986a)
	Winter vs. summer	OR = 1.93	Calf		Donovan *et al.* (1998a)
	Jan.-Feb. vs. rest year	OR = 2.6	Calf	Veterinarian-diagnosed	Virtala *et al.* (1999)
		OR = 3.7	Calf	Farmer-diagnosed	
Geographic region	West vs. mid-west	OR = 2.6	Herd	High vs. low mortality due to BRD	Losinger & Heinrichs (1996)
	South-east vs. mid-west	OR = 1.8	Herd		
	North-east vs. mid-west	RR = 0.63	Calf	Univariate analysis	Wells *et al.* (1996)
	South-east vs. mid-west	RR = 0.49	Calf		
Herd size	Per calving per year	OR = 1.02	Herd[2]	In winter	Waltner-Toews *et al.* (1986a)
		OR = 1.01	Herd	In summer	
	Per heifer present	Increased	Herd		Kimman *et al.* (1988)
	Per heifer present	Increased 0.12 times	Herd	Logit pneumonia, farmer-diagnosed	Van Donkersgoed *et al.* (1993)
		Increased 0.04 times	Herd	Logit pneumonia, veterinarian-diagnosed	
	≥ 6 vs. < 6 preweaned heifers in herd	RR = 2.2	Calf	Univariate analysis	Wells *et al.* (1996)
	Per animal present (incl. adults)	HR = 1.02	Herd		Norström *et al.* (2000)
Genetics	Various sires	OR per sire	Calf		Waltner-Toews *et al.*(1986a)
	Pure vs. crossbred[3]	RR = 0.47	Calf		Perez *et al.* (1990)
	Holstein relative to dairy and crossbred heifers	Increased 4.11 times	Herd	Logit pneumonia, farmer-diagnosed	Van Donkersgoed *et al.* (1993)
		Increased 2.92 times	Herd	Logit pneumonia, veterinarian-diagnosed	
Navel treatment	Other than chlorhexidine or iodine vs. not treated	OR = 2.94	Calf		Waltner-Toews *et al.* (1986a)
	Yes vs. not	RR = 0.41	Calf		Perez *et al.* (1990)
Antimicrobials preventively/previously	Yes vs. not	OR = 0.46	Calf		Waltner-Toews *et al.* (1986a, 1986d)
	Yes vs. not	OR = 0.40	Herd[2]	In winter	
	Yes vs. not	OR = 0.20	Calf	Farmer-diagnosed	Virtala *et al.* (1999)
Maternal antibody level	Specific IgG[4] titre (classes)	Decreased	Herd		Kimman *et al.* (1988)
		Decreased	Herd	Disease severity (scored)	

Table 2. (cont'd).

Risk factor	Risk factor levels	Association[1]	Level of analysis	Remarks	Reference
Maternal antibody level	Proportion (1 vs. 0) serum positive titres to IgG (> 800 mg dl^{-1}) in herd	OR = 0.41	Herd	Univariate analysis, veterinarian-diagnosed	Van Donkersgoed *et al.* (1993)
	Serum total protein (g dl^{-1})	Decreased	Calf	Curvilinear association	Donovan *et al.* (1998a)
		OR = 0.90	Calf	Ln(treatment days)	
	IgG ≤ 1200 mg dl^{-1} vs. > 1200 mg dl^{-1}	OR = 1.9	Calf	Veterinarian-diagnosed	Virtala *et al.* (1999)
Colostrum feeding	Assisted suckled vs. suckled	OR = 3.31	Calf		Waltner-Toews *et al.* (1986a)
Colostrum feeding x time of birth	Pail feeding x day-born calves vs. suckled	OR = 19.15	Calf		Waltner-Toews *et al.* (1986a)
Housing	Outdoor vs. indoor	Increased	Calf	Mortality due to BRD	Peters (1986)
	Outdoor hutches vs. individual indoor pens	OR = 0.04	Calf		Waltner-Toews *et al.* (1986a)
	Individual stall vs. pens	RR = 5.4	Calf	In one season-year only	Curtis *et al.* (1988a)
	Outdoor hutches vs. pens	RR = 5.1	Calf		
	Separate from older heifers vs. not	Decreased	Herd		Kimman *et al.* (1988)
	Indoor/outdoor hutches vs. not	OR = 0.5	Calf	Veterinarian-diagnosed	Virtala *et al.* (1999)
		OR = 0.4	Calf	Farmer-diagnosed	
	In presence of adults vs. not	OR = 1.9	Calf	Veterinarian-diagnosed	Virtala *et al.* (1999)
Other diseases previously	Scours < 14 days vs. not	RR = 2.5	Calf		Curtis *et al.* (1988a)
	Previous diarrhoea vs. not	RR = 3.8	Calf		Perez *et al.* (1990)
	Arcsin(scours < 14 days)$^{0.5}$ vs. not	OR = 4.9	Herd		Curtis *et al.* (1993)
Other diseases simultaneously	Scours < weaning vs. not	OR = 3.0	Calf		Waltner-Toews *et al.* (1986a)
	Scours < 90 days vs. not	RR = 3.1	Calf		Curtis *et al.* (1988a)
	Scours < 14 days x dullness < 90 days vs. not	RR = 6.0	Calf		Curtis *et al.* (1988a)
	Scours < 90 days x dullness < 90 days vs. not	OR = 6.3	Calf		Curtis *et al.* (1988a)
	Scours < weaning vs. not	OR = 2.2	Herd[2]	Above-median treatment days for scours, in winter	Waltner-Toews *et al.* (1986a)
	Scours < weaning vs. not	OR = 3.0		In summer	
	Dullness < 90 days vs. not	RR = 7.7	Calf		Curtis *et al.* (1988a)
	Arcsin(dull < 90 days)$^{0.5}$ vs. not	OR = 23.7	Herd		Curtis *et al.* (1993)

[1] Unless stated otherwise, associations refer to BRD as defined in the particular study (see Appendices 1 and 2).
[2] Above-median treatment days per calf.
[3] Heifers that – apart from milk production – also are used for beef production, or originate from this type of animals.
[4] IgG = Immunoglobulins.

ing were ambiguous. The risk of dystocia at first calving can increase, but this was quantified in one study only. Furthermore, an extended effect of BRD on the heifers' productivity after first calving is unlikely. A potential productivity effect of BRD caused by fertility disorders during the rearing period has not been investigated.

Risk factors

Season and region
The incidence of BRD was reported to be higher during winter months than during the summer period (Perez *et al.*, 1990). Heifers born during the winter (indoor) season were at an increased risk for BRD (Donovan *et al.*, 1998a; Virtala *et al.*, 1999) and were younger when they got the disease (Waltner-Toews *et al.*, 1986a) than those born during the summer (outdoor) season. But others could not confirm these results (Curtis *et al.*, 1988b; Perez *et al.*, 1990; Olsson *et al.*, 1993; Wells *et al.*, 1996). The observation period in these studies was relatively short, varying from about one year (Perez *et al.*, 1990; Olsson *et al.*, 1993; Wells *et al.*, 1996; Donovan *et al.*, 1998a; Virtala *et al.*, 1999) to nearly two years (Curtis *et al.*, 1988b) or 2.5 years (Waltner-Toews *et al.*, 1986c).

Data collected nationally on dairies in the USA showed that both the incidence of BRD (Wells *et al.*, 1996) and the mortality rates attributable to the disease (Losinger & Heinrichs, 1996) varied significantly with region.

Herd size
In many studies the incidence of BRD was found to be positively associated with herd size (Waltner-Toews *et al.*, 1986a; Kimman *et al.*, 1988; Van Donkersgoed *et al.*, 1993; Wells *et al.*, 1996; Virtala *et al.*, 1999; Norström *et al.*, 2000), but this effect could not be confirmed by the studies of Curtis *et al.* (1988a) and Olsson *et al.* (1993). The causes underlying the effect of herd size are unknown. It was suggested that larger herds might be at an increased risk of BRD due to more indirect contacts with other herds. In addition, in a large herd any infectious agent can establish itself more easily because of a greater degree of animal-to-animal contact (Norström *et al.*, 2000). Herd size may also be confounded with the number of visits from veterinarians and/or extension officers applying herd health programmes, which might result in BRD being recognized earlier and more readily. Or the disease may be an indirect measure of other management variables, such as stocking rate and overcrowding (Curtis *et al.*, 1988a; Van Donkersgoed *et al.*, 1993; Wells *et al.*, 1996).

Genetics and milk production
Pneumonia incidence during the pre-weaning period was found to be affected by the sire of the heifers, but this result was primarily caused by a few bulls whose daughters experienced higher treatment rates for pneumonia than the ones from other bulls (Waltner-Toews *et al.*, 1986a). In addition, several studies reported BRD to be associated with breed (dairy versus cross breeds) but the results were ambiguous (Perez *et al.*, 1990, Van Donkersgoed *et al.*, 1993); others found no effect (Olsson *et al.*, 1993; Virtala *et al.*, 1999). The associations between BRD, sire and breed could have

been partly related to the genetic component of calving ease selected for as part of the long-term breeding policy of the farmer (Waltner-Toews *et al.*, 1986a; Perez *et al.*, 1990) or by differences in genetic susceptibility to the disease (Van Donkersgoed *et al.*, 1993).

Herds with a high milk production were found to be less likely to have a high mortality rate due to BRD than herds with a low milk production. This could be related to genetic differences and to better management of the high-production herds (Losinger & Heinrichs, 1996).

Preventive treatment of dam

Prepartum vaccination of the dam against one or more of the most common respiratory viruses including BRSV (Van Donkersgoed *et al.*, 1993; Sivula *et al.*, 1996a) was not found to be associated with BRD. Prepartum vaccination of dams against scours was associated with an increased risk of pneumonia, both at herd and animal level (Waltner-Toews *et al.*, 1986a). Curtis *et al.* (1988a) and Sivula *et al.* (1996a) found no relation between prepartum vaccination of the dam against *Escherichia coli* and BRD. The prepartum administration of vitamins or selenium was not associated with BRD (Waltner-Toews *et al.*, 1986a).

Calving factors

Heifer calves born from primiparous cows (cows that calve for the first time) were more likely to develop BRD than calves from multiparous cows (Curtis *et al.*, 1988a), but a tendency for the opposite (Perez *et al.*, 1990) and no association (Olsson *et al.*, 1993) was also reported. Other variables related to calving ease, such as calving history, dystocia at birth and (routinely) assisted deliveries, were not found to be associated with the risk of BRD (Waltner-Toews *et al.*, 1986a; Curtis *et al.*, 1988a; Perez *et al.*, 1990; Sivula *et al.*, 1996a).

Heifer calves born on pasture appeared to have a shorter duration of pneumonia treatment and better two-week weight gains than heifers not born on pasture (Waltner-Toews *et al.*, 1986a). Furthermore, a good hygiene at the place of birth has shown to be negatively associated with BRD (Virtala *et al.*, 1999). Other studies found no relation between birthplace (Curtis *et al.*, 1988a; Perez *et al.*, 1990; Sivula *et al.*, 1996a; Virtala *et al.*, 1999) or related variables (Curtis *et al.*, 1993; Sivula *et al.*, 1996a) and the incidence of BRD.

Preventive treatment of heifers

The effect of navel disinfection of the new-born heifer on the risk of BRD is ambiguous. Perez *et al.* (1990) reported a protective effect, but no effect was reported of routine navel treatment on pneumonia risk at herd level by Waltner-Toews *et al.* (1986a) and, particularly, of chlorhexidine or iodine at individual level by Waltner-Toews *et al.* (1986a) and Sivula *et al.* (1996a). Moreover, compared with no navel treatment, using anything else but these two products was found to increase the new-born heifer's chances of pneumonia (Waltner-Toews *et al.*, 1986a).

A herd policy of using a medicated milk replacer or starter (Waltner-Toews *et al.*, 1986a) and the prophylactic administration of antimicrobials to individual heifers decreased the chances of pneumonia treatment (Waltner-Toews *et al.*, 1986a; Waltner-Toews *et al.*, 1986d; Virtala *et al.*, 1999). However, Sivula *et al.* (1996a) found no effect of routine injection of antibiotics at birth. In their study pneumonia risk increased for farms that routinely administered a coccidiostat before weaning. Others reported a detrimental effect of offering mineral supplements on the farm's pneumonia treatment days during winter (Waltner-Toews *et al.*, 1986a). In various studies vaccination of the new-born heifer against scours and the administration of vitamins or selenium appeared not significantly associated with BRD (Weiss *et al.*, 1983; Waltner-Toews *et al.*, 1986a; Curtis *et al.*, 1988a; Sivula *et al.*, 1996a; Virtala *et al.*, 1999). However, a study on *Escherichia coli* vaccination carried out on a large dairy heifer raising unit reported a protective effect on the risk of BRD (Daigneault *et al.*, 1991).

In a double blind field trial by Verhoeff & Van Nieuwstadt (1984) a live attenuated BRSV vaccine provided some protection against lower respiratory disease in dairy heifers. In two other studies no effect was found of preventive vaccination of heifers against BRSV (Ploeger *et al.*, 1986) or against one or more respiratory viruses, including BRSV (Sivula *et al.*, 1996a). Accordingly, a study on the use of prophylactic vaccination with *Pasteurella haemolytica* reported no effect on the incidence of BRD in dairy heifers (Stevens *et al.*, 1997).

Colostrum feeding

Colostrum – the first milk produced by the cow after giving birth – is particularly rich in nutrients and antibodies. New-born heifers with failure of passive transfer of colostral immunoglobulins were at an increased risk for BRD compared with heifers that received adequate colostral antibodies (Kimman *et al.*, 1988; Van Donkersgoed *et al.*, 1993; Donovan *et al.*, 1998a; Virtala *et al.*, 1999). Failure of passive transfer is also reported to increase the severity of clinical symptoms (Kimman *et al.*, 1988) and the number of treatment days required (Donovan *et al.*, 1998a). The chances of pneumonia treatment increased for new-born heifers that were assisted to suckle colostrum, perhaps because they were weak to begin with (Waltner-Toews *et al.*, 1986a). Furthermore, heifers that were given first colostrum by pail, specifically those born during the day, were at an increased risk for pneumonia compared with heifers that suckled (Waltner-Toews *et al.*, 1986a). The authors suggested that night-born heifers were likely to have suckled before the farmer initiated pail feeding in the morning. From several studies it appeared that the method of colostrum feeding, despite its often stated value, and related variables such as time after birth at which colostrum was first offered and amount of first colostrum fed, were not associated with BRD (Waltner-Toews *et al.*, 1986a; Curtis *et al.*, 1988a; Perez *et al.*, 1990; Curtis *et al.*, 1993; Olsson *et al.*, 1993; Sivula *et al.*, 1996a; Virtala *et al.*, 1999).

Weaning and feeding management

The moment when to wean heifers – a decision based on age, weight, or grain intake – was not associated with the risk of BRD (Sivula *et al.*, 1996a), although size-based weaning tended to increase the herd's chance of BRD (Curtis *et al.*, 1993).

Farms that offered fresh water to heifers, and farms that used pail feeding as opposed to nipple feeding subsequent to the colostral period reduced the chances of having above-median winter pneumonia treatment days (Waltner-Toews *et al.*, 1986a). Heifers that were fed more than five litres of milk replacer per day had a greater risk of BRD than those that were fed less (Perez *et al.*, 1990). Others did not find these or numerous other variables related to feeding after the colostral period – such as type of liquid feed fed, frequency of feeding and age at which starter was first offered – to be associated with BRD (Waltner-Toews *et al.*, 1986a; Perez *et al.*, 1990; Curtis *et al.*, 1993; Sivula *et al.*, 1996a; Virtala *et al.*, 1999).

Housing
Heifers raised in outdoor hutches were less likely to be treated for pneumonia than heifers raised in individual indoor pens (Waltner-Toews *et al.*, 1986a). Accordingly, Virtala *et al.* (1999) reported that housing in hutches, either indoors or outdoors, decreased the probability for developing pneumonia. In another study initial housing was found to affect BRD incidence, but effects depended on season and year and showed no consistent trends (Curtis *et al.*, 1988a). In an observational study at an intensive heifer-rearing unit the incidence of pneumonia did not differ between group and individual housing nor between outdoor and indoor housing, but mortality rates were higher for pneumonic heifers housed outdoors than for those housed indoors (Peters, 1986). Housing young heifers in the same building with older ones (Kimman *et al.*, 1988) or with adult cattle (Virtala *et al.*, 1999) has been reported to increase the risk of BRD. Accordingly, Ploeger *et al.* (1986) reported a negative relationship between the onset of a clinical BRSV infection and contact of young heifers with older cattle at pasture or after stabling. Contrary to what is often assumed, several others found no association between housing and BRD (Perez *et al.*, 1990; Curtis *et al.*, 1993; Van Donkersgoed *et al.*, 1993). Two factors related to housing that affected the risk of BRD included supplementary artificial light and frequency of changing bedding material (Perez *et al.*, 1990). But an effect of changing bedding material was not confirmed by Sivula *et al.* (1996a). Several other housing variables, such as bedding condition and floor type, were not found to be associated with BRD (Perez *et al.*, 1990; Curtis *et al.*, 1993; Sivula *et al.*, 1996a; Virtala *et al.*, 1999).

Dairies that housed pre-weaning heifers individually or in groups of six or less were less likely to be classified in the high BRD mortality rate category than dairies that housed heifers in groups of seven or more (Losinger & Heinrichs, 1996). On the other hand, Kimman *et al.* (1988) found no correlation between population density (number of heifers per m^3) and BRD. Criteria for grouping heifers after weaning, such as based on age or size (Curtis *et al.*, 1993; Sivula *et al.*, 1996a) and flow through group pens, including a continuous flow versus the 'all-in all-out' system (Sivula *et al.*, 1996a), were not found to be related with BRD.

Other diseases
Diarrhoea occurring either previously to BRD (Curtis *et al.*, 1988a; Perez *et al.*, 1990; Curtis *et al.*, 1993) or during the same period (Waltner-Toews *et al.*, 1986a; Curtis *et al.*, 1988a; 1993) increased the risk of BRD two to six times. Virtala *et al.* (1999), who could not confirm this association, argued that they probably had

missed cases of diarrhoea. BRD and diarrhoea could be caused by common agents, similar husbandry practices could predispose the animals to both diseases, heifers with diarrhoea could be more susceptible to BRD, or once a heifer has been treated for diarrhoea veterinarians and farmers may watch the animal more closely and diagnose BRD earlier than in the other heifers (Waltner-Toews *et al.*, 1986a). Heifers that were dull before the age of 90 days but exhibited no other detectable signs, were more likely to have BRD than their non-affected herd mates (Curtis *et al.*, 1988a; Curtis *et al.*, 1993). Dullness may in part be a separate disorder, but could also be a sign of BRD (Curtis *et al.*, 1993).

In summary, herd size and other diseases, especially diarrhoea, are evidently associated with the on-farm risk of BRD in dairy heifers. Season and colostrum feeding management presumably affect this risk. Effects of birth circumstances, housing and the prophylactic administration of antimicrobials are less clear, as are effects of region, genetics, and herd milk production level. Preventive vaccination does not affect the incidence of BRD, with the exception of vaccination against BRSV, which might be protective. Navel disinfection, preventive treatment of the dam prior to calving, and the criterion for the weaning decision do not seem to affect BRD incidence. Little work has been done on the association of BRD and feeding management after the colostral period.

Discussion

This review was restricted to peer-reviewed publications to ensure easy accessibility and generally good quality of the data obtained. Furthermore, as the variables of interest entailed multiple effects, confounding and interactions, the major interest was in epidemiological field studies that take into account the entire farm system. Moreover, the results had to be applicable to commercial dairy farms, thereby excluding experiments. The applied selection criteria resulted in observational field studies the majority of which were from the USA and only a few from Europe, in particular the Netherlands. So care must be taken when extrapolating the results to Dutch dairy farming conditions.

The review revealed that BRD reduces the heifers' productivity, but associations between the disease and the various production parameters and their magnitude, could not always be clearly demonstrated. The same holds for the risk factors of BRD in dairy heifers. So to date, quantitative insight into the productivity effects and risk factors of BRD in dairy heifers is lacking, and a precise evaluation of the economic losses due to BRD and the cost-effectiveness of prevention actions against the disease cannot yet be made. However, on account of the literature data several general recommendations for BRD prevention can be made that apply to heifers raised on Dutch dairy farms or under comparable conditions.

The first recommendation is to ensure that the new-born heifer receives enough colostral immunoglobulins soon after birth. Furthermore, the measures that reduce the on-farm incidence of BRD and other illnesses in dairy heifers, particularly diarrhoea, are promising. So improvement of the heifer's birthplace and housing circumstances, for instance by using outdoor hutches, seems to be important as well (Waltner-Toews *et al.*, 1986a; Curtis *et al.*, 1988a; Perez *et al.*, 1990; Frank & Kaneene, 1992; Curtis *et al.*, 1993). As the present study shows that these factors may be associated with BRD and as they are also known to be important from earlier work, future research should focus on further quantification of their impact. The fact that less than 10% of the heifers kept on commercial dairy farms is housed in individual hutches (Mourits *et al.*, 2000) justifies more research on the impact of this factor.

Herd size, herd intensity (defined as livestock units ha^{-1}), milk production and breed vary widely among Dutch dairy farms (Mourits *et al.*, 2000) and could have a considerable impact on the on-farm incidence of BRD. However, these factors cannot be easily modified and are therefore not relevant for short-term prevention of the disease. The association between herd size and BRD could be related to the concepts of herd immunity: the larger the herd, the more likely it is that both infectious and susceptible animals will be present, maintaining the spread of infection on the farm. So at large dairy farms prevention of BRD should be specially aimed at measures that increase the animal's resistance to clinical symptoms of the disease, for instance by adequate colostrum management.

The effect of season may be important for the incidence of BRD on Dutch dairy farms because of the general preference of calving during autumn and winter when milk prices are higher (Mourits *et al.*, 2000). Winter calving almost always occurs indoors, resulting in many heifers born and raised under less favourable conditions for BRD prevention. Changing the calving pattern to summer, on pasture, may reduce the on-farm incidence of BRD.

Though not investigated exhaustively, the effect of preventive vaccination of the new-born heifer against BRSV could be beneficial. The survey of Mourits *et al.* (2000) showed that on 30% of the Dutch dairy farms new-born heifers are vaccinated against BRSV. So the impact of this factor should be further investigated in a series of well-designed field trials.

The studies on productivity effects and risk factors of BRD in dairy heifers only focused on the disease occurring before the age of six months and not during the months thereafter. Data from Dutch dairy farms (Mourits *et al.*, 2000) showed that BRD also occurs after the age of six months, although less frequently than before that age. However, because of the higher age of affected heifers the economic impact of the disease might be substantial. So future research should include heifers older than six months.

Conclusion and future outlook

At present, field study data do not reveal an overall quantitative insight into the productivity effects and risk factors of BRD in Dutch dairy heifers or in heifers raised under comparable conditions. Literature data on most of the parameters are either incomplete or ambiguous, and quantitative data to accurately evaluate the economic losses due to BRD on Dutch dairy farms and the cost-effectiveness of prevention actions against the disease are lacking. Additional data can possibly be obtained from experimental work preferably dealing with natural infections in a controlled environment. In addition, more research will be needed focusing on the complete period from birth to calving and not only on the pre-weaning period.

References

Anonymous, 1994. Dairy Heifer Morbidity, Mortality, and Health Management focusing on Preweaned Heifers. National Dairy Heifer Evaluation Project, USA. (http://www.aphis.usda.gov/vs/ceah/cahm/Dairy Cattle/ndhep/hepdes2.pdf)

Britney, J.B., S.W. Martin, J.B. Stone & R.A. Curtis, 1984. Analysis of early calfhood health status and subsequent dairy herd survivorship and productivity. *Preventive Veterinary Medicine* 3: 45–52.

Correa, M.T., C.R. Curtis, H.N. Erb & M.E. White, 1988. Effect of calfhood morbidity on age at first calving in New York Holstein herds. *Preventive Veterinary Medicine* 6: 253–262.

Curtis, C.R., J.M. Scarlett, H.N. Erb & M.E. White, 1988a. 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., H.N. Erb & M.E. White, 1988b. Descriptive epidemiology of calfhood morbidity and mortality in New York Holstein herds. *Preventive Veterinary Medicine* 5: 293–307.

Curtis, C.R., M.E. White & H.N. Erb, 1989. Effects of calfhood morbidity on long-term survival in New York Holstein herds. *Preventive Veterinary Medicine* 7: 173–186.

Curtis, C.R., H.N. Erb, J.M. Scarlett & M.E. White, 1993. Path model of herd-level risk factors for calfhood morbidity and mortality in New York Holstein herds. *Preventive Veterinary Medicine* 16: 223–237.

Daigneault, J., M. Thurmond, M. Anderson, J. Tyler, J. Picanso & J. Cullor, 1991. Effect of vaccination with the R mutant *Escherichia coli* (J5) antigen on morbidity and mortality of dairy calves. *American Journal of Veterinary Research* 52: 1492–1496.

Donovan, G.A., I.R. Dohoo, D.M. Montgomery & F.L. Bennett, 1998a. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. *Preventive Veterinary Medicine* 34: 31–46.

Donovan, G.A., I.R. Dohoo, D.M. Montgomery & F.L. Bennett, 1998b. Calf and disease factors affecting growth in female Holstein calves in Florida, USA. *Preventive Veterinary Medicine* 33: 1–10.

Frank, N.A. & J.B. Kaneene, 1992. Management risk factors associated with calf diarrhoea in Michigan dairy herds. *Journal of Dairy Science* 76: 1313–1323.

Kaneene, J.B. & H.S. Hurd, 1990. The National Animal Health Monitoring System in Michigan. III. Cost estimates of selected dairy cattle diseases. *Preventive Veterinary Medicine* 8: 127–140.

Kimman, T.G., G.M. Zimmer, F. Westenbrink, J. Mars & E. Van Leeuwen, 1988. Epidemiological study of bovine respiratory syncytial virus infections in calves: influence of maternal antibodies on the outcome of disease. *Veterinary Record* 123: 104–109.

Losinger, W.C. & A.J. Heinrichs, 1996. Management variables associated with high mortality rates attributable to respiratory tract problems in female calves prior to weaning. *Journal of the American Veterinary Medical Association* 209: 1756–1759.

Miller, G.Y. & C.R. Dorn, 1990. Costs of dairy cattle diseases to producers in Ohio. *Preventive Veterinary Medicine* 8: 171–182.

Mourits, M.C.M., H.J. Van Der Fels-Klerx, R.B.M. Huirne & M.W.C. Huyben, 2000. Dairy-heifer management in the Netherlands: A field survey. *Preventive Veterinary Medicine* 46: 197–208.

Nagel, E. (Ed.), 2002. Gale Directory of Databases, Vol. 1: Online Databases. Gale Group, Inc., Farmington Hills, Michigan, USA.

Noordhuizen, J.P.T.M., K. Frankena, C.M. Van Der Hoofd & E.A.M. Graat, 1997. Application of Quantitative Methods in Veterinary Epidemiology. Wageningen Press, Wageningen, 445 pp.

Norström, M., E. Skjerve & J. Jarp, 2000. Risk factors for epidemic respiratory disease in Norwegian cattle herds. *Preventive Veterinary Medicine* 44: 87–96.

Olsson, S.-O., S. Viring, U. Emanuelsson & S.-O. Jacobsson, 1993. Calf diseases and mortality in Swedish dairy herds. *Acta Veterinaria Scandinavica* 34: 263–269.

Perez, E., J.P.T.M. Noordhuizen, L.A. Van Wuijkhuise & E.N. Stassen, 1990. Management factors related to calf morbidity and mortality rates. *Livestock Production Science* 25: 79–93.

Peters, A.R., 1986. Some husbandry factors affecting mortality and morbidity on a calf-rearing unit. *Veterinary Record* 119: 355–357.

Ploeger, H.W., J.H. Boon, C.H.L. Klaassen & G. Van Florent, 1986. A sero-epidemiological survey of infections with the bovine respiratory syncytial virus in first-grazing calves. *Journal of Veterinary Medicine B* 33: 311–318.

Quigley III, J.D., C.S.T. Nyabadza, G.B. Benedictus & A. Brand, 1996. Monitoring replacement rearing: Objectives and materials and methods. In: A. Brand, J.P.T.M. Noordhuizen & Y.H. Schukken (Eds.), Herd Health and Production Management in Dairy Practice. Wageningen Press, Wageningen, pp. 75–102.

Radostits, O.M., D.C. Blood, C.C. Gay, J.H. Arundel, B.O. Ikede & R. MacKenzie, 1994. Veterinary Medicine: A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses (8th ed.). Bailliere Tindall, London, 1763 pp.

Roy, J.H.B., 1990. The Calf. Vol. 1: Management and Health (5th ed.). Butterworths, London, 258 pp.

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

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

Stevens, R.D., R.P. Dinsmore, R.P. Ellis & M. Katsampas, 1997. Morbidity and mortality in young Holstein calves vaccinated with a P. haemolytica leukotoxoid. *Large Animal Practice* 18: 23–29.

Thrusfield, M., 1995. Veterinary Epidemiology (2nd ed.). Blackwell Science Ltd, Oxford, 483 pp.

Van Der Fels-Klerx, H.J., L.H.J. Goossens, H.W. Saatkamp & H.S. Horst, 2002. Elicitation of quantitative data from a heterogeneous expert panel: Formal process and application in animal health. *Risk Analysis* 22: 67–81.

Van Donkersgoed, J., C.S. Ribble, L.G. Boyer & H.G.G. Townsend, 1993. Epidemiological study of enzootic pneumonia in dairy calves in Saskatchewan. *Canadian Journal of Veterinary Research* 57: 247–254.

Verhoeff, J. & A.P.K.M.I. Van Nieuwstadt, 1984. Prevention of bovine respiratory syncytial virus infection and clinical disease by vaccination. *Veterinary Record* 115: 488–492.

Virtala, A-M.K., G.D. Mechor, Y.T. Gröhn & H.N. Erb, 1996a. The effect of calfhood diseases on growth of female dairy calves during the first 3 months of life in New York State. *Journal of Dairy Science* 79: 1040–1049.

Virtala, A-M.K., G.D. Mechor, Y.T. Gröhn, H.N. Erb & E.J. Dubovi, 1996b. Epidemiologic and pathologic characteristics of respiratory tract disease in dairy heifers during the first three months of life. *Journal of the American Veterinary Medical Association* 208: 2035–2042.

Virtala, A-M.K., Y.T. Gröhn, G.D. Mechor & H.N. Erb, 1999. The effect of maternally derived immunoglobulin G on the risk of respiratory disease in heifers during the first 3 months of life. *Preventive Veterinary Medicine* 39: 25–37.

Waltner-Toews, D., S.W. Martin & A.H. Meek, 1986a. 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., S.W. Martin & A.H. Meek, 1986b. The effect of early calfhood health status on survivorship and age at first calving. *Canadian Journal of Veterinary Research* 50: 314–317.

Waltner-Toews, D., S.W. Martin, A.H. Meek & I. McMillan, 1986c. Dairy calf management, morbidity and mortality in Ontario Holstein herds. I. The data. *Preventive Veterinary Medicine* 4: 103–124.

Waltner-Toews, D., S.W. Martin & A.H. Meek, 1986d. Calf-related drug use on Holstein dairy farms in southwestern Ontario. *Canadian Veterinary Journal* 27: 17–22.

Warnick, L.D., H.N. Erb & M.E. White, 1994. The association of calfhood morbidity with first-lactation calving age and dystocia in New York Holstein herds. *Kenya Veterinarian* 18: 177–179.

Warnick, L.D., H.N. Erb & M.E. White, 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, L.D., H.N. Erb & M.E. White, 1997. The relationship of calfhood morbidity with survival after calving in 25 New York Holstein herds. *Preventive Veterinary Medicine* 31: 263–273.
Weiss, W.P., V.F. Colenbrander, M.D. Cunningham & C.J. Callahan, 1983. Selenium/Vitamin E: role in disease prevention and weight gain in neonatal calves. *Journal of Dairy Science* 66: 1101–1107.
Wells, S.J., L.P. Garber & G.W. Hill, 1996. Health status of preweaned dairy heifers in the United States. *Preventive Veterinary Medicine* 29: 185–199.

Appendix 1

Definition of BRD types and measures of association

BRD TYPES[1]

Calf pneumonia
Cases of BRD observed one after the other, periodically or the whole year round, mostly occurring in the first three months of life. They can be caused by a variety of primary pathogens, but are commonly caused by bacteria, mainly *Pasteurella* spp., and preceded by an infection with respiratory viruses.

BRD outbreak
A number of heifers in a group suddenly show clinical signs. BRD outbreaks mostly occur during the housing period. Affected dairy heifers are usually older than three months, but also younger heifers can be affected. Cases of BRD outbreak mostly are caused by a primary viral infection, mainly with *Bovine Respiratory Syncytial Virus*, with or without a secondary bacterial infection (Van Der Fels-Klerx *et al.*, 2002).

MEASURES OF ASSOCIATION

Relative Risk (RR)
RR is the ratio of disease incidence in exposed animals to the disease incidence in unexposed animals. RR > 1 indicates a positive statistical association between factor and disease; RR < 1 indicates a negative statistical association. RR = 1 suggests no association (Thrusfield, 1995; pp. 224–225).

Odds Ratio (OR)
OR is a relative measure based on 'odds'. It is defined as the ratio of the probability of an event occurring to the probability of the event not occurring. In a cohort study a disease OR is estimated, which is the ratio of the probability of disease incidence in exposed individuals to the probability of disease incidence in unexposed ones. In a case-control study the exposure OR is determined, which is the ratio of the probability of exposure to the factor in cases to the probability of exposure in controls. In a cross-sectional study a prevalence OR is determined (Thrusfield, 1995; pp. 225–227).

Hazard Ratio (HR)
HR is the ratio of the average hazard rate in the exposed group to the average hazard rate in the non-exposed group. The average hazard rate is calculated as the total number of disease cases divided by their total time at risk. If HR > 1 the factor is positively associated to the disease incidence. HR < 1 indicates a negative association, and HR = 1 indicates no association (Noordhuizen *et al.*, 1997; pp. 181–202).

[1] The definitions apply to BRD in dairy heifers in the Netherlands not caused by lungworm.

Appendix 2

Background information on epidemiological field studies on productivity effects and risl

Region, Country	Period of data collection	Number of herds	Number of animals	Study period
Ontario, Canada	Born during an almost 8-year period	2[1]	460[2]	Birth to 4 months
UK	Entering during a 3.5-year period	1[3]	1996	1–6 weeks
The Netherlands	Cross-sectional	123	–	–
Ontario, Canada	Born during a 2.5-year period	35	1968	Liveborn to weaning
New York, USA	Born during an almost 2-year period	26	1171	1–90 days
Friesland, the Netherlands	Present at start and born during a 3-month period	21	434	Birth to 1 year
Utrecht, the Netherlands	Born during 1-year period, followed until last-born was 4 months old	63	919	Birth to 4 months
Sweden	Born during about 1-year period, followed until	131	4839[2]	Liveborn to 90 days
	last-born was 3 months old	–	885[2]	91 days to 12 –15 months
Saskatchewan, Canada	Born during 4.5-month period, followed until last-born was 6 months/ end study	17	325[2]	Birth to 6 months/end of study
28 states, USA	3-month period, retrospective	1685	47,057	Birth to weaning
Minnesota, USA	Born during 1-year period, followed until last-born was 16 weeks old	30	845	Birth to 16 weeks
New York, USA	Born during 1-year period, followed until last-born was 3 months old	18	410	Birth to 3 months
28 states, USA	Present at start and born during 1-year period	906	12,228	Liveborn to 8 weeks
Florida	Born during 1-year period, followed until the age of 6 weeks	2	3103	2 days to 6 months; 6–14 months
2 veterinary districts, Norway	5-month period, retrospective	431[10]	–	–

[1] Institutional herds.
[2] Few males included.
[3] Intensive rearing unit with dairy bred calves.
[4] Herd level incidence.
[5] Data also used by Waltner-Toews *et al.* (1986b, 1986d).

actors of Bovine Respiratory Disease (BRD) in dairy heifers

Basis of diagnosis of BRD	Crude BRD incidence (%)	Reference
Clinical signs and treatment for BRD, by farmer and/or veterinarian	ca. 5.8	Britney *et al.* (1984)
Clinical signs of pneumonia, by farmers and/or veterinarian	48.3	Peters (1986)
Clinical BRSV infection confirmed by veterinarian	18.5[4]	Ploeger *et al.* (1986)
Treatment for pneumonia, by farmer	15.4	Waltner-Toews *et al.* (1986a, 1986c)[5]
Clinical signs of BRD, by farmer	7.4	Curtis *et al.* (1988b)[6]
Clinical signs of BRD, by farmer and/or veterinarian	–	Kimman *et al.* (1988)
Clinical signs of BRD, by veterinarian	5.8	Perez *et al.* (1990)
Clinical signs of coughing/ pneumonia, by farmer	0.8	Olsson *et al.* (1993)
	1.6	
Clinical signs of pneumonia, by veterinarian	26	Van Donkersgoed *et al.* (1993)
Treatment for pneumonia, by farmer	39	
Mortality due to BRD, by farmer	–	Losinger & Heinrichs (1996)
Treatment for pneumonia, by farmer	7.6	Sivula *et al.* (1996a)[7]
Clinical signs of BRD, by veterinarian	25.6	Virtala *et al.* (1996a)[8]
Treatment for BRD, by farmer unless done on advice of veterinarian	11	
Treatment for BRD, by farmer, verified by veterinarian	17.3	
Clinical signs of BRD, by farmer	8.4	Wells *et al.* (1996)[9]
Clinical signs and treatment for pneumonia,	21	Donovan *et al.* (1998a, 1998b)
by farm personnel	1	
Clinical signs of herd outbreak of BRD, by veterinarian	35[4]	Norström *et al.* (2000)

[6] Data also used by Correa *et al.* (1988), Curtis *et al.* (1988a, 1989, 1993), Warnick *et al.* (1994, 1995, 1997).
[7] Data presented in Sivula *et al.* (1996b).
[8] Data presented in Virtala *et al.* (1996b); data also used by Virtala *et al.* (1999).
[9] For more information see Anon. (1997).
[10] Various herd types with dairy cattle of all ages.