Results and Evaluation of Thirty Years of Health Recordings in the Norwegian Dairy Cattle Population

O. Østerås,*†¹ H. Solbu,‡§ A. O. Refsdal,‡ T. Roalkvam,|| O. Filseth,‡ and A. Minsaas#

*Department of The Norwegian Cattle Health Services, TINE Norwegian Dairies BA, 1431 Ås, Norway

†Department of Production Animals Clinical Sciences, Norwegian School of Veterinary Science, 0033 Oslo, Norway

‡GENO Breeding and AI Association, 2326 Hamar, Norway

§Norwegian Quality System for Agriculture, 0135 Oslo, Norway

||Department of The Norwegian Dairy Herd Recording System, TINE Norwegian Dairies BA, 1431 Ås, Norway

#Norwegian Veterinary Association, 7710 Sparbu, Norway

ABSTRACT

The results are based on the Norwegian Cattle Health Recording System, which has been in place for the entire country since 1975. The dairy breeds in Norway consist of 94% Norwegian Red and 4% crossbreeds with Norwegian Red. No other breed consists of more than 0.5% of the total population. During the past 30 yr, there have been 11,563,692 dairy cows within the recording system, corresponding to 8,633,532 cow-years and 8,632,516 calvings. This population consisted of 3,038,675 first-calving cows. Altogether, 8,435,704 different diagnoses were recorded from 4,444,485 different cows each year. The general trend for all recordings was an increase in the incidence rate of all cases from 0.74 per 365 d at risk (cow-year) in 1976 to 1.36 in 1990, and then a decrease to 0.62 in 2002. The corresponding figures for cows treated per cow-year were 0.44 up to a maximum of 0.82, and then a decrease to 0.46 per cow-year in 2002. The most common diseases were acute (severe to moderate) clinical mastitis, chronic (mild) clinical mastitis, ketosis, milk fever, teat injuries, retained placenta, silent heat or anestrus, indigestion, cystic ovaries, and metritis. Clinical mastitis increased from 0.15 cows treated per cow-year in 1975 to 0.44 in 1994, and then decreased to 0.23 in 2002. Ketosis began at 0.10 in 1975, increased to 0.24 in 1985, and then decreased to 0.05 in 2005. For several of the most common diseases, there was a reduction of more than 50% from the 1990s to the years after 2000. Validation processes confirmed that this fluctuation reflected the general trend in the population. The disease recording system also reflected the known outbreaks of bovine respiratory syncytial virus during 1976, 1989 to 1990, and 1995. A marked increase in malformation diagnoses

could be seen in 1986 and in 1989 and 1990. These could be related to the Chernobyl nuclear power plant accident in April 1986. The diagnosis that showed the most stability throughout these 30 yr was retained placenta. The 3 main reasons for the large fluctuation for many of the diseases could be the following: a breeding effect, an effect of preventive work, and an effect of changing the therapeutic attitude. Many of the actions taken to bring about improvements would not have been possible without a functioning and practical recording system. Our experience is that an organ-related diagnosis system with up to 60 or 70 different diagnoses will meet the needs of the dairy industry.

Key words: recording system, bovine health, disease recording

INTRODUCTION

Animal identity, production, and disease recordings are all essential parts of good dairy farm management, progeny testing of bulls, and good prevention of disease and quality assurance systems. Several countries have recordings of production organized within an animal recording system (International Committee for Animal Recording, 2007). Usually these recordings involve production data, such as calvings, removals, daily milk yield, and data from milk analyses such as SCC, fat, and protein. Very few involve data from veterinary treatments (Pauw et al., 2004).

In some countries, systematic epidemiological surveys of disease incidences in dairy production have been organized, such as the National Animal Health Monitoring System in the United States (Kaneene and Hurd, 1990) and others in Canada (Sargeant et al., 1998; van Dorp et al., 1999). However, only a few countries have reported disease recordings from the majority of the dairy cattle population within the framework of an animal recording system. These countries are Norway (Solbu, 1983), Sweden (Emanuelsson and Oltanacu, 1998), Finland (Saloniemi and Roine, 1981), and Den-

Received January 14 2007.

Accepted May 28, 2007.

¹Corresponding author: olav.osteras@veths.no

mark (Bartlett et al., 2001). Norway began its disease recording system in 1975–1976. Solbu (1983, 1984a,b) has previously published some of these data.

The intention of this paper is to present the organization of the Norwegian Cattle Health Recording System (NCHRS) in the past and at present, the experiences with 2 different coding systems, and an evaluation of the results obtained during a 30-yr span from 1975–1976 through 2006, and further to discuss these results with special reference to present and future use of the data.

MATERIALS AND METHODS

The Historical Beginning from 1974

The NCHRS began as a test project, and from September 1, 1975, the recording system covered the entire country. This system was based on a joint venture between the Norwegian Veterinary Association and the Norwegian Red Cattle Association (now named GENO Breeding and AI Association). The data were reported to the Norwegian Red Cattle Association until 1979 and later to the Norwegian Dairies Association (now named TINE Norwegian Dairies BA) as a part of the Norwegian Dairy Herd Recording System (NDHRS). The essential steps in the development of the NCHRS are presented in Table 1.

The Norwegian Act and Notes on Health Cards

The Norwegian Act, concerning distribution of products within veterinary medicine, states that all sales of such preparations should be retailed by official pharmaceutical stores and can only be administered as treatments by authorized veterinarians or prescribed by them after examination of the animal and a professional diagnosis of the disease of the animal in question. Thus, all treatments with antibiotics, hormones, or both in dairy cattle have to be made primarily by a veterinarian (Grave and Wegener, 2006). The veterinarian has to code, describe, and sign off on all diagnoses and treatments of individual dairy cattle on a Cow Health Card at the time of the cowshed visit (Ministry of Agriculture and Food, 2002). The design of the card can be found at http://storfehelse.tine.no/dok/helsek_ku01.jpg. Each dairy cow has its own health card, organized in a health binder placed in the cowshed, that is easily available at the time of a veterinary visit.

Reporting and Structure on Database

Periodically (once a month), the records from the Cow Health Cards are reported by the Dairy Herd Improvement Services into the mainframe of the NDHRS. The

complete structure of these data tables and more detailed information is available at www.kkvvet.no. The data are processed annually to create the official annual reports of the NDHRS and the NCHRS (Norwegian Dairy Herd Recording System, 1976–2006).

The Norwegian Dairy Association joined the formal agreement of the Norwegian Cattle Health Card System in 1979, and in 1989 the official Veterinary Authorities also joined. In this way, data from the Norwegian Cattle Health Card System from 1989 became part of the official disease reporting system for dairy cattle in Norway. From 1996 the responsibility of coordinating the disease codes for production diseases was turned over from the official authorities to the Norwegian Cattle Health Services (NCHS). For more information, consult <http://storfehelse.tine.no>. From the start of the recordings, the diseases expected to be most prevalent were given a unique number from 1 to 43. The code numbers from 50 to 56 were introduced in 1979 (see Table 2). In 1989 the coding system was totally rearranged to an organ-related coding system (Table 2), in which each 100 represents diseases related to separate organ systems. A coding system for the preventive therapy of each disease was achieved by adding 500 to the disease code. Thus, code 766 is a preventive treatment of disease code 266, parasitic disease. From August 1999 a few new disease codes on reproduction and udder health (Table 2) were introduced and, at the same time, the name of acute clinical mastitis was changed to severe and moderate clinical mastitis, and chronic clinical mastitis was changed to mild clinical mastitis in accordance with the recommendations of the International Dairy Federation (1997). This paper deals only with the results from dairy cattle with records from first calving until removal from the herd.

Calculated Incidence Rates

The results in this paper are based on the annual reports from 1974–1975 through 2005 of the NDHRS, NCHS, and its predecessors. Only dairy cows within the NDHRS during the complete year in question were entered into the study. The incidence rates are recalculated from all raw data to present incidences in accordance with current international recommendations (International Dairy Federation, 1997).

The incidence rates of diseases are calculated according to Martin et al. (1987) and Kleinbaum et al. (1982). The incidence rate (incidence density) is defined as the number of cows with one or more events of disease treatment divided by the number of cow-years at risk within one calendar year (**COW_RATE**). According to the International Dairy Federation recommendations on presentation of mastitis-related data (International

Table 1. Essential steps in the development of the Norwegian Cattle Health Recording System, including those that could be expected to have an impact on disease incidence

Year	Development	Impact on
1975	The Norwegian Cattle Health Recording System was started in all dairy herds that were members of the Norwegian Dairy Herd Recording System, by the Norwegian Veterinary Association and the GENO Breeding and AI Association.	All diseases
1978	Disease records were used in estimating a progeny index for bulls.	The main production diseases
1978	Bulk milk somatic cell counting (BMSCC) as well as composite milk somatic cell counting were introduced in Norway. Reports on BMSCC were sent to advisers and veterinarians twice a year.	Mastitis
1979	The diagnosis of clinical mastitis was split into 2, acute and chronic.	Mastitis
1980	Premium quality for BMSCC below 250,000 cells/mL was introduced.	Mastitis
1980	Weighting on clinical mastitis in progeny testing was increased to 7.4% of total weight.	Mastitis
1982	The Norwegian Udder Health Control Program was established by the Norwegian Dairy Association and the Norwegian Animal Health Authorities.	Mastitis
1982	The Norwegian Milk Quota System was introduced.	Ketosis and other related diseases
1989	A new organ-related health code system was introduced.	All diseases
1989	Herd incidence rates were reported annually and given to local veterinarians and advisers.	The main production diseases
1989	Data management in the Norwegian Dairy Herd Recording System was restructured.	Several diseases
1992	The test project for The Norwegian Cattle Health Services was established in 25% of the Norwegian herds.	The main production diseases
1995	The Norwegian Cattle Health Services was established in the entire country.	The main production diseases
1996	Separate health reports were given periodically (every second month) to all dairy farmers.	All diseases
1997	Weighting on clinical mastitis in progeny testing was increased to 21%.	Mastitis
1999	Some new disease codes were introduced for mastitis and reproduction.	Mastitis and reproduction
2000	The Norwegian Agricultural Quality Assurance System (KSL) was introduced, with premium quality payment for milk and meat.	All diseases
2002	The milk quota was made available for sale.	Production
2005	The Claw Health Card was introduced to make notes at claw trimming.	Claw diseases
2005	Health data were made available on the Internet and were presented to herd managers and disease prevention managers.	All diseases

Dairy Federation, 1997), the number of such events is defined as the number of cows with the event during a specified year. The number of cow-years at risk is defined as the sum of the total number of days for each cow within the herd during the specific year, adding up all days from the first day at first calving until the culling day, all within the specified year. A new case of a diseased cow will be calculated despite the occurrence of the same event in any earlier year. The number of cow-years at risk is corrected in accordance with International Dairy Federation (1997) recommendations. This is based on the assumption that, on average, during any one year, the event happens halfway through the lifetime of the cow that year. The mean lifetime of the cows was calculated by dividing the total number of cow-years by the total number of cows in the population during the year in question. Thus, each diseased cow is not at risk during half the mean number of days that cow represents when calculating the total cow-years in the current year. The formula for this calculation is:

$$\text{incidence rate (incidence density) COW_RATE} = \frac{N_COW_TREAT}{(COW_YEARS - [(COW_YEARS / N_COW) \times 0.5] \times N_COW_TREAT)},$$

where N_COW_TREAT is the number of cows having at least one case of the actual disease, COW_YEARS is the total number of cow-years within the whole population during the year in question, and N_COW is the total number of cows in the population during the year in question.

For the 10 diseases most frequently encountered throughout the complete period, the treatment incidence rate (TREAT_RATE) was calculated. The TREAT_RATE was defined as the number of recorded treatments divided by the total number of cow-years within the population; thus:

$$TREAT_RATE = N_TREAT / COW_YEARS,$$

where N_TREAT is the number of recorded treatments for the actual disease code during one year, and COW_YEARS is the total number of cow-years within the whole population during the specified year. The variation in COW_RATE between years was estimated as the standard deviation of the COW_RATE each year, also divided by the overall mean COW_RATE multiplied by 100, or percent standard deviation.

Table 2. Incidence rate per 100 cow-years (COW_RATE) of dairy cows treated for a specified disease event recorded during the study period and each fifth year

Code before 1989	Code after 1989	Disease name	Total numbers of cows with recording	Mean COW_RATE 1975–1988 ¹	Mean COW_RATE 1989–2005 ¹	COW_RATE 1975–1976	COW_RATE 1980	COW_RATE 1985	COW_RATE 1990	COW_RATE 1995	COW_RATE 2000	COW_RATE 2005
Infectious diseases (not notifiable, nor serious infectious diseases formerly defined as groups A and B by the OIE ²)												
35 11	215	Malignant catarrhal fever	479		0.010				0.010	0.011	0.010	0.009
		Tetanus	241	0.006		0.012	0.006	0.007				
		Actinomycosis	279	0.007		0.008	0.004	0.010				
	249	Other infectious diseases	5,446		0.116				0.089	0.120	0.128	0.200
Diseases of the respiratory, cardiovascular, and hematopoietic system												
	250	Disease of the cardiovascular system	1,625		0.035				0.041	0.041	0.032	0.023
26	251	Disease of the respiratory tract	14,068	0.106	0.211	0.045	0.099	0.094	0.214	0.376	0.208	0.208
27	252	Lungworm infestation	537	0.010	0.003	0.014	0.009	0.018	0.004	0.001	0.002	0.011
28		Lung disease	2,152	0.054		0.034	0.049	0.058				
16		Hemoglobinuria	944	0.024		0.019	0.019	0.029				
18		Heart disease and pericarditis	1,100	0.028		0.017	0.025	0.031				
	259	Other diseases	1,399		0.030				0.035	0.037	0.023	0.020
Diseases of the digestive system												
24	260	Indigestion	103,315		2.226				3.161	2.697	1.464	1.263
	261	Colic, gastrointestinal or abomasal dislocation	18,704	0.139	0.283	0.044	0.134	0.160	0.307	0.364	0.239	0.204
22	262	Traumatic gastritis	96,906	1.274	1.003	0.627	1.186	1.551	1.420	1.093	0.763	0.667
20		Acute indigestion	63,703	1.621		0.767	1.508	1.812				
29	265	Gastritis, enteritis	34,637	0.464	0.349	0.317	0.401	0.536	0.516	0.401	0.227	0.168
30	266	Parasitic diseases	1,770	0.021	0.020	0.013	0.018	0.030	0.017	0.022	0.023	0.022
	267	Dental diseases	1,623		0.035				0.038	0.039	0.032	0.015
	268	Bloat	2,377		0.051				0.058	0.057	0.035	0.034
13		Peritonitis	1,011	0.026		0.029	0.037	0.030				
25		Liver diseases	1,216	0.031		0.017	0.047	0.035				
	279	Other diseases	10,041		0.215				0.297	0.245	0.160	0.130
Skin diseases, including hoofs and claws												
53	280	Decornuation caused by injury	979		0.021				0.023	0.023	0.026	0.014
21	281	Laminitis	85,533	0.872	1.098		0.682	1.417	1.660	1.238	0.750	0.496
	282	Claw diseases	39,372	0.449	0.463	0.392	0.552	0.292	0.367	0.410	0.526	0.596
	283	Louse infestation	2,691		0.057				0.007	0.021	0.086	0.185
	284	Tumors	621		0.013				0.018	0.018	0.011	0.004
	286	Wounds or injuries caused by the stall, except teat injury	5,805		0.124				0.189	0.134	0.095	0.077
37	287	Wounds, injuries (other than 286)	27,522	0.531	0.140	0.311	0.509	0.595	0.177	0.153	0.111	0.086
19	288	Unspecified skin diseases	747		0.016				0.017	0.013	0.012	0.010
		Skin diseases	767	0.019		0.014	0.020	0.024				
	299	Other diseases	1,137		0.020				0.000	0.000	0.000	
Diseases of the mammary gland												
10	300	Agalactiae (absence of milk)	918		0.020				0.021	0.022	0.021	0.012
	301	Agalactiae (failure of milk ejection)	4,316	0.046	0.087	0.007	0.046	0.085	0.093	0.104	0.087	0.061
52	302	Extirpation of supernumerary teats	999	0.010	0.013		0.008	0.017	0.016	0.014	0.010	0.009
08	303	Acute clinical mastitis	1,702,266	21.424	21.182	14.759	23.112	22.115	25.805	26.073	17.528	14.857
50	304	Chronic clinical mastitis	784,361	4.671	13.501		0.672	8.651	14.678	19.030	11.214	9.393
56	305	Subclinical mastitis	75,974	0.115	1.535		0.017	0.170	0.877	2.710	1.613	0.811
06	306	Teat injuries	352,888	4.066	4.223	2.535	3.543	4.755	5.960	5.207	3.150	2.162
07		Narrow teat	28,460	0.722		1.061	1.397	0.121				
54		Congenital deficiency	564	0.014			0.009	0.026				

Continued

Table 2 (Continued). Incidence rate per 100 cow-years (COW_RATE) of dairy cows treated for a specified disease event recorded during the study period and each fifth year

Code before 1989	Code after 1989	Disease name	Total numbers of cows with recording	Mean COW_RATE 1975–1988 ¹	Mean COW_RATE 1989–2005 ¹	COW_RATE 1975–1976	COW_RATE 1980	COW_RATE 1985	COW_RATE 1990	COW_RATE 1995	COW_RATE 2000	COW_RATE 2005
54		Congenital deficiency	564	0.014			0.009	0.026				
	308	Udder edema	141		0.013						0.035	0.041
	309	Wound between the udder and thigh	86		0.007						0.020	0.019
	310	Dry cow therapy	222		0.098						0.053	0.585
	319	Other diseases	18,977		0.406				0.523	0.545	0.294	0.181
Reproductive diseases, obstetrical conditions												
14/51/55	320	Uterine prolapse	20,999	0.303	0.193	0.148	0.330	0.371	0.210	0.229	0.151	0.182
	321	Torsion of the uterus	10,748		0.230				0.230	0.270	0.207	0.191
	322	Prolonged gestation	10,606		0.227				0.253	0.307	0.176	0.129
38	323	Dystocia	106,933	0.932	1.509	0.330	0.780	1.269	1.682	1.743	1.390	1.167
31	324	Malformation	1,794	0.018	0.023	0.008	0.026	0.022	0.052	0.026	0.011	0.008
	325	Vaginal prolapse	7,975		0.171				0.226	0.191	0.127	0.145
03	326	Retained placenta	339,544	4.161	3.907	3.026	4.213	4.274	5.035	4.578	3.047	3.090
	329	Other diseases	6,846		0.146				0.204	0.176	0.109	0.092
Diseases of the reproductive and urinary tracts												
09	330	Abortion	26,102	0.326	0.283	0.249	0.339	0.402	0.378	0.335	0.217	0.167
00	331	Silent heat, anestrus	292,257	2.908	3.869	1.020	2.321	4.299	5.374	4.365	3.385	1.707
	332	Heat synchronization	26,728		0.573				0.600	0.694	0.515	0.586
02	333	Metritis, vaginitis, or salpingitis	136,795	1.754	1.459	1.487	1.853	1.916	2.041	1.764	1.061	0.918
01	334	Cystic ovaries	149,174	1.988	1.529	1.667	1.853	2.257	1.943	1.722	1.289	1.122
39	336	Inflammation of the urinary tract	1,322	0.017	0.014	0.015	0.028	0.019	0.019	0.004	0.013	0.010
33		Kidney disease	245	0.006		0.003	0.005	0.006				
	340	Silent heat	463		0.185						0.158	1.010
	341	Silent repeated breeding	133		0.048						0.046	0.199
	349	Other diseases	11,937		0.255				0.411	0.291	0.165	0.156
Diseases of the nervous system and sense organs												
17		Central nervous system diseases	251	0.006		0.005	0.005	0.006				
	359	Others	2,252		0.048				0.038	0.032	0.068	0.048
Diseases of the musculoskeletal system												
12	360	Tendonitis and bursitis	9,021		0.193				0.280	0.236	0.125	0.124
	361	Fractures	1,735	0.015	0.024	0.017	0.015	0.016	0.027	0.028	0.020	0.022
23	364	Arthritis at age >6 mo, also tendonitis and bursitis	43,076	0.540	0.465	0.296	0.564	0.568	0.524	0.590	0.419	0.390
32	365	Muscular degeneration	1,231	0.009	0.018	0.010	0.012	0.010	0.026	0.019	0.019	0.012
	366	Paresis caused by pelvic and muscular injury	5,294		0.113				0.126	0.123	0.102	0.094
	379	Other diseases	7,522		0.161				0.178	0.181	0.115	0.160
Systemic diseases												
	380	Abscesses or phlegmons	12,877		0.276				0.257	0.311	0.273	0.261
	381	Abnormal behavior	982		0.021				0.025	0.019	0.021	0.014
15	382	Poisoning	3,351	0.048	0.031	0.065	0.064	0.035	0.039	0.035	0.031	0.028
	384	Hypomagnesemia or grass tetany	9,015		0.192				0.246	0.201	0.183	0.151

Continued

Table 2 (Continued). Incidence rate per 100 cow-years (COW_RATE) of dairy cows treated for a specified disease event recorded during the study period and each fifth year

Code before 1989	Code after 1989	Disease name	Total numbers of cows with recording	Mean COW_RATE 1975–1988 ¹	Mean COW_RATE 1989–2005 ¹	COW_RATE 1975–1976	COW_RATE 1980	COW_RATE 1985	COW_RATE 1990	COW_RATE 1995	COW_RATE 2000	COW_RATE 2005
05	385	Ketosis	1,135,492	18.026	10.435	10.269	13.634	23.880	17.531	10.947	6.057	4.556
04	386	Milk fever, parturient paresis	551,363	7.505	5.740	6.114	7.720	6.839	7.959	6.332	4.252	4.912
	387	Paresis, except for parturient paresis	11,844		0.253				0.329	0.297	0.226	0.176
	388	Deficit of vitamins or minerals	4,278		0.091				0.045	0.094	0.105	0.074
36		Tumors	1,376	0.035		0.030	0.044	0.041				
	399	Other diseases	13,089		0.280				0.420	0.297	0.210	0.163
Prophylactic treatments												
	766	Parasitic diseases	691		0.015					0.004	0.016	0.058
42	803–805	Mastitis	41,330	0.755	0.247	0.273	0.947	0.980	0.627	0.251	0.076	0.062
43	885	Ketosis	3,546	0.041	0.041	0.000	0.020	0.085	0.089	0.029	0.020	0.030
41	886	Milk fever	64,437	0.792	0.712	0.286	0.952	0.789	1.020	0.959	0.495	0.284
All other diseases, all diseases and total number of cow-years for each year period												
40		Other diseases not classified above	100,416	2.179	0.321		2.634	2.983	0.297	0.271	0.295	0.163
		Total number of treated cows	4,444,485	62.310	64.979	83,122	126,484	175,175	179,778	173,266	123,858	98,131
		Total number of all diseases (cases)	8,435,704	94.352	100.547	190,890	267,316	369,778	386,091	345,183	205,804	154,077
		Total number of cow-years	8,633,532	3,955,660	4,677,872	258,824	282,227	300,873	285,874	282,133	270,028	241,647

¹Mean value for these years.²OIE = World Organization for Animal Health.

RESULTS

Baseline Population

There was an increase from 46% of herds within the NDHRS in 1975 to 95% in 2005. The corresponding percentage of cows in these herds increased from 67 to 97%. The dairy cows included in this database consist of 94% Norwegian Red Cattle and 4% crossbreeds with Norwegian Red Cattle. No other breed constituted more than 0.5% of the population. During the same period, the number of cow-years within the NDHRS was stable, from 258,824 cow-years in 1975 to 273,856 in the year 2001. There was a peak in 1984, with 303,296 cow-years. For all the other years, the figures were between 280,000 and 290,000 cow-years. Since 2001 the number of cow-years has decreased every year, and in 2005 the number was 241,647 cow-years. The mean number of cow-years varied from 11.3 per herd in 1975 to 16.7 in 2005.

The mean milk yield produced per cow-year increased in the population from 5,428 kg in 1975 to 6,403 kg in 1993. From 1993 until 2000, the milk production per cow-year was considered stable because of the milk quota system. Later, it increased again to a level of 6,605 kg per cow-year until 2005. The composition of the feed consisted mainly of grass silage (28.4% of the energy content in 1975 to 41.0% in 2005), concentrate (38.6% in 1975 to 36.8% in 2000, up to 39.9% in 2005), and pasture (22.9% in 1975 to 13.9% in 1992, up to 16.7% in 2002). Other minor feed components were hay (5.5% in 1975 to 0.5% in 2005) and roots (3.4% in 1975 to 0.05% in 2005). Other feedstuffs constituted 1.2% of total feed in 1995 and up to 7.3% in 1993.

Altogether, 4,444,485 cows were recorded with one or more diseases during the 30 yr of health recording of Norwegian dairy cattle. A total of 8,435,704 disease cases were observed in a base population of 8,633,532 cow-years and 8,632,516 calvings. A total of 11,563,692 individual dairy cows were represented for one or more days during the 30 yr. This represents the largest database of continuous recording of disease for dairy cattle that we are aware of. The incidence rate for all diseases, cows treated for any disease, estimated incidence risk ($1 - e^{-\text{COW_RATE}}$) for any disease, and number of recorded treatments per treated cow each year from 1975 through 2005 is presented in Figure 1.

Incidence Rates

The total number and mean number of recordings for each event from 1975–1976 through 2005 are presented in Table 2, as well as the incidence rate (COW_RATE) every fifth year. Overall, the most frequent disease recordings were for acute (severe and moderate) clinical

mastitis (21.28 ± 3.99 per 100 cow-years); ketosis (13.83 ± 6.42); chronic (mild) clinical mastitis (9.40 ± 4.70), milk fever (6.54 ± 1.47), and teat tramps (4.15 ± 1.22); retained placenta (3.99 ± 0.65); absence of heat (3.43 ± 1.43); cystic ovaries (1.74 ± 0.38); metritis (1.59 ± 0.39); and dystocia (1.24 ± 0.42). The COW_RATE for these diseases is illustrated in Figures 2 to 5.

Variation in Incidence Rates

The largest deviation, estimated by standard deviation compared with the overall mean, was for the following treatments and diseases: preventive therapy of parasitic diseases (with a standard deviation of 221% compared with the overall mean), louse infestation (181%), subclinical mastitis (94%), lungworm infestation (87%), narrow teats (81%), wounds and injuries (61%), congenital teat deficiency (58%), malformation of the reproductive tract (52%), and chronic (mild) clinical mastitis (50%).

The most stable disease COW_RATE from year to year, expressed as the percentage standard deviation compared with the overall mean, was for the following disease records: retained placenta (16%), heat synchronization (18%), paresis caused by pelvic and or muscular injury (19%), severe and moderate clinical mastitis (19%), abscesses and phlegmons (20%), arthritis (21%), parasitic disease (22%), cystic ovaries (22%), milk fever (23%), and abortion (24%).

Number of Treatments per Diseased Cow

Table 3 presents the TREAT_RATE and Table 4 presents the number of treatments per treated cow of the most prevalent diseases from 1994 to 2005, such as clinical mastitis, ketosis, milk fever, teat tramps, absence of heat, and retained placenta. The number of treatments per treated cow showed a decreasing trend from 1994 through 2005 for all diseases. Ten diseases had less than 1.06 treatments per treated cow, on average, during the period 1994 through 2005. These diseases were dystocia, retained placenta, prolonged gestation, torsion of the uterus, decornuation caused by injury, abortion, malformation, fractures, uterine prolapse, and extirpation of supernumerary mammary teats. Ten diseases had more than 1.25 treatments per treated cow, on average, during the period 1994 to 2005. These diseases were arthritis (1.38), milk fever (1.38), ketosis (1.36), abscesses and phlegmons (1.36), diseases of the respiratory tract (1.36), acute (severe) clinical mastitis (1.34), deficit of vitamins or minerals (1.30), hoof diseases (1.28), malignant catarrhal fever (1.26), and colic, gastrointestinal dislocation, and dislocation of the abomasum (1.26).

Figure 1. Incidence rate of cases per cow-year for all diseases, incidence rate of cows treated for any disease per cow-year, estimated incidence risk (cumulative incidence), and number of recorded treatments per treated cow from 1975 through 2005.

DISCUSSION

The NCHRS is a recording scheme for treatment of diseases or preventive therapy given to dairy cattle. The diseases recorded are therefore primarily those that are treated or judged by the farmers as needing treatment. This is important to recognize because, despite the fact that there is quality assurance through a veterinary diagnosis, the farmer has to call on the veterinarian before diagnosis and treatment. The point at which a veterinarian is contacted to treat animals can be at different levels on different farms. This threshold and the incidence rate can be seen as an investment in the farming system. Whether this investment is at the optimal level according to the farmer's goals of economic income, lifestyle, and taking care of the animals' welfare is questionable. The threshold set by the farmer will obviously be different for different diseases. Such herd clustering of clinical mastitis treatment was demonstrated by a correlation of 0.25 between animals within the same herd, as identified by Whist and Østerås (2007). For milk fever and reproduction treatment, a very small or no such correlation could be found (Sogstad et al., 2006).

Study Population

The study population comprised all herds within the NCHRS and NDHRS. The disease incidence for the whole country would be biased if the incidence differed between those herds that are not members and those that are. The proportion of cows that are members is greater than the proportion of herds. This indicates that herds outside the system have relatively fewer cows. The annual reports (Norwegian Dairy Herd Recording System, 1976–2006) indicate that the incidence of disease treatment is higher in smaller herds than in larger herds under Norwegian conditions. This means that the underestimation of incidence rates for the total Norwegian cattle population is more pronounced for the 1970s than for the 1990s. It is obvious that the relative value of one single cow, compared with the value of the whole herd, is higher in smaller herds than in larger herds. The farmer will therefore have a higher investment interest in treatment to keep the cow within smaller herds. This could have the effect that the treatment rate is higher, assuming that the true disease rate is the same.

Figure 2. Incidence rate per cow-year of cows with acute or chronic clinical mastitis during the period 1975 through 2005.

Incidence Rates

The different calculation techniques can cause a difference in disease rate by more than 30% within the same population (International Dairy Federation, 1997). The main goal of this study was to present incidence trends in the Norwegian population of dairy cattle throughout 30 yr, year by year. The data available were the number of cows diagnosed with any disease according to the coding system presented in Table 2 for each year, and the base population with the number of cow-years observed from first calving to slaughter or removal within the period of January 1 through December 31 each year. This is why some treatments that rationally occur only once during a lactation, such as dystocia, still show a repeated treatment per diseased cow of 1.02. A number greater than 1 indicates that 2 calvings could occur within 1 yr of observation. The number of cow-years at risk was the closest estimate to the true incidence rate available and will be correct, assuming that, on average, the disease event would occur halfway between calving and the end of lactation.

The estimated treatment rate will reflect the frequency of treatments per cow-time. For a population

this will be the true rate of therapy for a specific disease in the population in any cow, whether treated earlier or not. For diseases that are not very common, the treatment rate and incidence rate would be almost equal.

Most Common Diseases Compared with Other Surveys. Clinical mastitis is also the most common disease in other studies in the literature that present disease rates. A study from France revealed that the most common disease in dairy cattle was clinical mastitis (with 44.1 cases per 100 calvings), locomotor disorders (with 10.9 cases), digestive disorders (with 5.1 cases), retained placenta (with 8.8 cases), dystocia (with 6.6 cases), milk fever (with 5.6 cases), and chronic metritis (with 5.1 cases; Fourichon et al., 2001). The largest difference compared with our study was the difference in locomotor disorders. This could be because Norway has relatively few claw problems in tie-stall systems and very few cases of infectious digital dermatitis (Sogstad et al. 2005). A study from Denmark revealed an incidence rate of clinical mastitis of 36 to 48 cases per 100 cow-years at risk (Bartlett et al., 2001). A British study covering 340 herds had 36.6% mastitis, 23.7%

Figure 3. Incidence rate per cow-year of cows treated for clinical ketosis, milk fever, or indigestion during the period 1975 through 2005.

lameness, 5.3% hypocalcemia, 8.7% assisted calving, 1.3% digestive diseases, 0.7% hypomagnesemia, and 0.4% ketosis (Whitaker et al., 2000). The 5 most frequent diseases in Finland were acute mastitis (17.0%), anestrus (8.1%), ovarian cysts (7.3%), milk fever (5.4%), and ketosis (4.9%), according to Rajala and Gröhn (1998). The mastitis incidence rates from different countries vary from 0.14 cases per 365 cow-days through 0.48 cases per 365 cow-days (Barkema et al., 1998; Sargeant et al., 1998; Beaudeau et al., 2002; Peeler et al., 2002). During the period under consideration in the present paper, the same variation within the Norwegian population was estimated to be between 0.50 in 1994 and 0.25 cases of clinical mastitis per 365 cow-days at risk. This illustrates similar variation within Norway during 10 yr as was reported from different countries during recent years. This is important, because it illustrates that an accurate quantification of disease incidence cannot be made simply by monitoring disease over a single year.

Number of Treatments per Treated Cow. Some of the diseases that are very frequent, such as ketosis and mastitis, may occur several times during the lactation. Other diseases are more infrequent, but when they oc-

cur they are very difficult to treat. Examples of these hard-to-treat diseases are arthritis, phlegmons, respiratory diseases, hoof diseases, and malignant catarrhal fever. The reported incidence of malignant catarrhal fever in this study was 0.1 per 1,000 animals, whereas from Switzerland an incidence of 0.6 per 1,000 was reported (Muller-Dublies et al., 2001). These numbers are probably underestimated, because the Norwegian data in this paper consisted only of milking cows and not young stock.

Diseases with a low number of treatments per diseased cow were those that respond very well to therapy or those that, when veterinarians are called, mean there is a problem that has to be solved at once. For some of these diseases, it is typical that if they cannot be cured, the animal will be slaughtered.

Effect of Introducing New Codes. When new disease codes were introduced, as in 1979, 1989, and 1999, it would typically take about 5 yr before the new coding system was functioning well in the field. This was especially true for the differentiation of the clinical mastitis codes in 1979. In 1989, when the whole coding system was extensively changed, all the health cards were centrally preprinted with the cow identity and all the pre-

Figure 4. Incidence rate of cows with treatments of teat tramps and subclinical mastitis during the period 1975 through 2005.

viously reported codes for that cow. This ensured the quality of results when this large change was performed.

Trends in the Most Common Diseases. The increase in clinical mastitis from the 1980s is probably because of increased awareness on the part of farmers of the need to keep the bulk milk SCC at a low level to satisfy the requirements of the quality payment system. Typically, there has been an increase in treatment of chronic (mild) cases. The decrease from 1994 onward has 3 main causes. One is an action by the producers' organization to reduce the unnecessary use of antibiotics. The second is the effect of the breeding program, as documented by Heringstad et al. (2003), who demonstrated a genetic improvement in the Norwegian cattle population from 1990 onward. The third cause is the establishment of NCHS in 1995 and a good reporting system with available data that can be used as a production management tool.

The other major disease change is the increase in ketosis, with an incidence rate at 0.14 per cow-year in 1980, an increase to 0.24 per cow-year in 1985, and then a decrease from the mid-1980s to a relative low incidence of 0.04 in 2005. The increase is probably a

result of the management and feeding strategy when the quota system was introduced in January 1982. Under the quota situation, it is a goal to produce a certain amount of milk as cheaply as possible. In this situation, some farmers may have reduced the feeding of concentrates. The reduction of ketosis in recent years is probably caused by a greater awareness of and concern about the ketosis problem and subsequent adjustment to feeding and the feeding strategy from the 1990s onward. Cows have more free access to high-quality roughage and a better distribution of concentrates during the day. Finally, during 2005, the incidence rate of ketosis was lower than for milk fever, which is also typical for other countries (Fourichon et al., 2001).

The decrease in teat tramps from 1989 could partly be due to the focus on milking management and pulsator function after it was revealed that the milking process and the milking machine were the most important risk factors for teat tramps (Østerås et al., 1990; Østerås et al., 1995).

The increase in treatment of anestrus from 1980 could be caused by access to new medicines, such as prostaglandins to treat silent heat. The decrease from the middle of the 1980s could be linked to the decrease in

Figure 5. Incidence rate of cows with treatments of retained placenta, absence of heat, and cystic ovaries during the period 1975 through 2005.

ketosis because of the positive relationship between ketosis and reproductive diseases such as anestrus and cystic ovaries (Refsdal, 1982; Fourichon et al., 2000). The decrease in therapy for retained placenta could be caused by the change in treatment strategy from active removal to the more common nonremoval treatment strategy practiced from the 1990s onward. Research

has shown little difference between those 2 strategies (Drillich et al., 2003).

Variation in Disease Treatments. The incidence of respiratory disease showed marked spikes in 1976, 1990, and 1995 (Figure 6). This could be because of well-known epidemic outbreaks of bovine respiratory syncytial virus in parts of Norway during those years

Table 3. Incidence rate of treatments (TREAT_RATE) as the number of treatments per cow-year of the 10 most prevalent diseases during 1994 through 2005, ranked according to incidence in 2005

Code	Disease	TREAT_RATE for 365 d, by year							
		1994	1995	1996	1997	1998	1999	2000	2005
303	Acute clinical mastitis (severe and moderate)	0.363	0.335	0.285	0.270	0.243	0.224	0.209	0.177
304	Chronic clinical mastitis (mild)	0.232	0.236	0.195	0.168	0.147	0.131	0.128	0.106
386	Milk fever	0.098	0.088	0.078	0.070	0.066	0.058	0.056	0.065
385	Ketosis	0.188	0.148	0.140	0.119	0.093	0.077	0.077	0.057
326	Retained placenta	0.046	0.046	0.040	0.038	0.039	0.037	0.031	0.031
331	Silent heat, anestrus (from 1999)	0.055	0.053	0.047	0.046	0.047	0.044	0.039	0.019
341	Silent heat (separate from 1999)							0.008	0.011
306	Teat injuries	0.064	0.061	0.055	0.051	0.044	0.038	0.035	0.024
260	Indigestion	0.033	0.030	0.028	0.024	0.023	0.019	0.016	0.014
334	Cystic ovaries	0.020	0.019	0.018	0.017	0.016	0.014	0.014	0.012
333	Metritis	0.023	0.017	0.017	0.016	0.016	0.014	0.012	0.011

Table 4. Number of treatments per treated cow of the 10 most prevalent diseases during 1994 to 2005, ranked according to the figures in 2005

Code	Disease	Number of treatments per treated cow per year							
		1994	1995	1996	1997	1998	1999	2000	2005
386	Milk fever	1.42	1.42	1.39	1.38	1.36	1.35	1.34	1.36
385	Ketosis	1.43	1.40	1.40	1.36	1.33	1.30	1.30	1.27
303	Acute (severe and moderate) clinical mastitis	1.44	1.40	1.35	1.33	1.30	1.28	1.27	1.26
333	Metritis	1.20	1.00	1.19	1.20	1.19	1.17	1.18	1.18
304	Chronic (mild) clinical mastitis	1.34	1.32	1.27	1.23	1.21	1.21	1.19	1.16
306	Teat injuries	1.20	1.19	1.17	1.17	1.15	1.15	1.14	1.13
260	Indigestion	1.13	1.13	1.13	1.13	1.14	1.13	1.12	1.12
331	Silent heat	1.21	1.22	1.20	1.18	1.18	1.17	1.15	1.11
334	Cystic ovaries	1.14	1.13	1.13	1.12	1.11	1.10	1.12	1.10
326	Retained placenta	1.02	1.02	1.01	1.01	1.01	1.01	1.02	1.01

(Norström et al., 2001). After each peak of disease in the respiratory tract, the general level was established at a higher level than before. This could be because a new strain of bovine respiratory syncytial virus was introduced, as probably was the case in 1995 when the introduction was caused by an import of live animals from Denmark (Norström et al., 2001). The increased treatment of louse infestation with the introduction of eradication programs (Nafstad and Grønstøl, 2001) fits well with the experience that lice and external parasites have been more common and more commonly treated in recent years.

The marked peak of diagnosis code 324 (malformation related to the reproductive tract or newborn calves) in the years 1989 through 1991 (Figure 6) could be linked to the Chernobyl nuclear power plant catastrophe in the last week of April 1986. The peak occurred 3 to 5 yr after the fallout of radionuclides Cs_{134} and Cs_{137} . There is also a distinct but smaller peak in the year 1986. These 2 peaks are significant, and there could be 2 reasons for this finding. Either there was more attention to malformations after Chernobyl, or there was a true increase in malformations because of the biological effects of radionuclides deposited over

Figure 6. Incidence rate of cows per cow-year with treatments of diseases of the respiratory tract and malformations related to the reproductive tract or to a newborn calf during the period 1975 through 2005.

certain areas of Norway. More recently, the incidence of this diagnosis has reduced continuously to a lower level than ever before. In the Norwegian human population, an association was identified between total radiation dose and hydrocephaly. No associations were found, however, for conditions previously reported to be associated with radiation, namely, small head circumference, congenital cataracts, anencephaly, spina bifida, and low birth weight (Lie et al., 1992).

The decrease in diagnosis and therapy of narrow teats from 1980 through 1988 could be because of genetic selection for milkability. Milkability has a high heritability of 0.37 ± 0.12 (Miller et al., 1976), and the trait was introduced into the breeding program both at the sire level (national level) and at the dam level (herd-level selection). The trait reached such a low level that the diagnosis was removed from the recording system.

Validity

When diseases are recorded under practical farming conditions, there will always be some reasons for misclassification. Such misclassification could be because of simple errors in writing down individual numbers, diagnosis codes, and treatment dates. The errors could occur at the veterinary level, the farmer level, or the reporter level. Some of these errors could be identified as diagnoses in males that usually occur only in females, or diagnoses before calving for those that should only occur after calving. Some errors will always be hidden within the large number of other relevant diagnoses. Such errors will usually occur at a higher proportional rate for those diagnoses that are very infrequent compared with the more common diagnoses. Accordingly, our experience has been that figures on events that are diagnosed less than 50 times per year should be judged and evaluated with great care. The figures from Table 2 for diseases such as tetanus, actinomycosis, and kidney disease were therefore removed from the coding system in 1989. Currently, the Norwegian disease code for production animals includes 67 different diagnoses. Our experience is that there is no need for additional differentiation because diseases with low frequency are not robust. The recording system will be used mainly for daily management at the farm level, survey of the disease situation, and animal breeding. If there is a need for research on more infrequently occurring diseases, then the research should be designed in a way that is different from general surveys. The organ-related system makes it easy to add new diagnosis codes, as was done in 1999, if there are available codes under that organ system. The system is thus robust for certain changes.

At present, the NCHS is working on different evaluation processes for such data. There has been a comparison of retail sales of intramammary drugs used for mastitis therapy and the incidence rate of clinical mastitis throughout the 30 yr. These comparisons revealed very parallel curves for incidence and retail sales. This indicates that even if some data are missing, the same proportion is missing every year. This ensures that the reduction in mastitis treatment recorded from 1994 through 2003 is a true reduction, because it is also reflected in the retail sales of intramammary drugs for mastitis therapy.

There is an urgent need for good validation processes as the need for health records increases for daily farm management, breeding purposes, and traceability. More research should be done to evaluate the performance in practice of such validations.

The organ-related code system from 1989 made it easier to identify a certain disease code. A precise scientific diagnostic code system could very easily be too detailed and be a source of more misclassification. The NCHRS is completely integrated into daily practical farming needs and is incorporated into the national breeding program, which is also driven by farmers.

The experience with NCHRS for dairy cattle has shown some promising results, because it has extended awareness of the high incidence rates for both mastitis and ketosis throughout the 1980s. Since 1994 it has been the most important tool to decrease the overall treatment rate by more than 50% by means of management tools, information processes, periodical reports, and breeding programs. The continuous recording for several diseases also demonstrates a huge variation over the years, illustrating that a national survey for 1 yr would not reliably indicate the level 5 yr later. One example is that both mastitis and ketosis declined considerably in the course of a few years in Norway, mastitis by 52% and ketosis by 75%. Such reductions would be impossible without knowing the incidence rate in each year and, on this basis, setting goals and evaluating progress. Access to the data is also essential for breeding purposes and scientific research to be able to make further improvements.

REFERENCES

- Barkema, H. W., Y. H. Schukken, T. J. Lam, M. L. Beiboer, H. Wil-mink, G. Benedictus, and A. Brand. 1998. Incidence of clinical mastitis in dairy herds grouped in three categories by bulk milk somatic cell counts. *J. Dairy Sci.* 81:411–419.
- Bartlett, P. C., J. F. Agger, H. Houe, and L. G. Lawson. 2001. Incidence of clinical mastitis in Danish dairy cattle and screening for non-reporting in a passively collected national surveillance system. *Prev. Vet. Med.* 48:73–83.
- Beaudeau, F., C. Fourichon, H. Seegers, and N. Bareille. 2002. Risk of clinical mastitis in dairy herds with a high proportion of low individual milk somatic-cell counts. *Prev. Vet. Med.* 53:43–54.

- Drillich, M., A. Pfutzner, H. J. Sabin, M. Sabin, and W. Heuwieser. 2003. Comparison of two protocols for the treatment of retained fetal membranes in dairy cattle. *Theriogenology* 59:951–960.
- Emanuelsson, U., and P. A. Oltanacu. 1998. Incidences and effects of disease on the performance of Swedish dairy herds stratified by production. *J. Dairy Sci.* 81:2376–2382.
- Fourichon, C., F. Beaudeau, N. Bareille, and H. Seegers. 2001. Incidence of health disorders in dairy farming systems in western France. *Livest. Prod. Sci.* 68:157–170.
- Fourichon, C., H. Seegers, and X. Malher. 2000. Effect of disease on reproduction in the dairy cow: A meta-analysis. *Theriogenology* 53:1729–1759.
- Grave, K., and H. C. Wegener. 2006. Comment on: Veterinarians' profit on drug dispensing. *Prev. Vet. Med.* 77:306–308.
- International Committee for Animal Recording. 2007. Subject: ICAR home page. <http://www.icar.org/index.htm> Accessed Jan. 13, 2007.
- International Dairy Federation. 1997. Recommendations for Presentation of Mastitis-Related Data. *Bull. Int. Dairy Fed.* No. 321. Int. Dairy Fed., Brussels, Belgium.
- Heringstad, B., R. Rekaya, D. Glanola, G. Klemtsdal, and K. A. Welgel. 2003. Genetic change for clinical mastitis in Norwegian cattle: A threshold model analysis. *J. Dairy Sci.* 86:369–375.
- Kaneene, J. B., and H. S. Hurd. 1990. The National Animal Health Monitoring System in Michigan. I: Design, data and frequencies of selected dairy diseases. *Prev. Vet. Med.* 8:103–114.
- Kleinbaum, D. G., L. L. Kupper, and H. Morgenstern. 1982. *Epidemiologic Research: Principles and Quantitative Methods*. Van Nostrand Reinhold, New York, NY.
- Lie, R. T., L. M. Irgens, R. Skjærven, J. B. Reitan, P. Strand, and T. Strand. 1992. Birth defects in Norway by levels of external and food-based exposure to radiation from Chernobyl. *Am. J. Epidemiol.* 136:377–388.
- Martin, S. W., A. H. Meek, and P. Willeberg. 1987. *Veterinary Epidemiology: Principles and Methods*. Iowa State Univ. Press, Ames.
- Miller, R. H., R. E. Pearson, B. T. Weinland, and L. A. Fulton. 1976. Genetic parameters of several measures of milk flow rate and milking time. *J. Dairy Sci.* 59:957–964.
- Ministry of Agriculture and Food. 2002. Forskrift om merking, registrering og rapportering av dyr [Regulation of identification, recording and reporting on production animals]. <http://www.lovdata.no/cgi-wift/lides?doc=/sf/sf/20020903-0970.html> Accessed Dec. 16, 2006. (in Norwegian)
- Muller-Dublies, U. U., J. Egli, H. Li, U. Braun, and M. Ackermann. 2001. Malignant catarrhal fever in Switzerland. 1. Epidemiology. *Schweiz. Arch. Tierheilkd.* 143:173–183.
- Nafstad, O., and H. Grønstøl. 2001. Eradication of lice in cattle. *Acta Vet. Scand.* 42:81–89.
- Norström, M., V. L. Edge, and J. Jarp. 2001. The effect of an outbreak of respiratory disease on herd-level milk production of Norwegian dairy farms. *Prev. Vet. Med.* 51:259–268.
- Norwegian Dairy Herd Recording System. 1976–2006. Årsrapporter [Annual reports]. TINE Norwegian Dairies, Ås, Norway. (in Norwegian)
- Østerås, O., O. Rønningen, L. Sandvik, and S. Waage. 1995. Field studies show association between pulsator characteristics and udder health. *J. Dairy Res.* 62:1–13.
- Østerås, O., I. Vågsholm, and A. Lund. 1990. Teat lesions with reference to housing and milking management. *J. Vet. Med. A* 37:520–524.
- Pauw, R., S. Mack, and J. Maki-Hokkonen. 2004. Development of animal identification and recording systems for developing countries. ICAR Techn. Ser. No. 9. Proc. ICAR/FAO Seminar, Sousse, Tunisia. http://www.icar.org/Documents/technical_series/tc_series_09_sousse.pdf Accessed Jan. 13, 2007.
- Peeler, E. J., M. J. Green, J. L. Fitzpatrick, and L. E. Green. 2002. Study of clinical mastitis in British dairy herds with bulk milk somatic cell counts less than 150,000 cell/ml. *Vet. Rec.* 151:170–176.
- Rajala, P. J., and Y. T. Gröhn. 1998. Disease occurrence and risk factor analysis in Finnish Ayrshire cows. *Acta Vet. Scand.* 39:1–13.
- Refsdal, A. O. 1982. Ovarian cysts in dairy cattle. *Norsk Veterinærtidsskrift [Norwegian Vet. J.]* 94:789–796. (in Norwegian, with English summary)
- Saloniemi, H., and K. Roine. 1981. Incidence of some metabolic diseases in dairy cows. *Nord. Vet. Med.* 33:289–296.
- Sargeant, J. M., H. M. Scott, K. E. Leslie, M. J. Ireland, and A. Bashiri. 1998. Clinical mastitis in dairy cattle in Ontario: Frequency of occurrence and bacteriological isolates. *Can. Vet. J.* 39:33–38.
- Sogstad, Å. M., T. Fjeldaas, O. Østerås, and K. Plym-Forsell. 2005. Prevalence of claw lesions in Norwegian dairy cattle housed in tie stalls and free stalls. *Prev. Vet. Med.* 70:191–209.
- Sogstad, Å. M., O. Østerås, and T. Fjeldaas. 2006. Lameness and claw lesions related to reproductive performance and production diseases. *J. Dairy Sci.* 89:2519–2528.
- Solbu, H. 1983. Disease recording in Norwegian dairy cattle. Part I. Disease incidences and non-genetic effects on mastitis, ketosis and milk fever. *Z. Tierzucht. Zuechtungsbiol.* 100:139–157.
- Solbu, H. 1984a. Disease recording in Norwegian dairy cattle. Part II. Heritability estimates and progeny testing for mastitis, ketosis and “all diseases.” *Z. Tierzucht. Zuechtungsbiol.* 101:51–58.
- Solbu, H. 1984b. Disease recording in Norwegian dairy cattle. Part III. Factors affecting diseases related to reproductive performance. *Z. Tierzucht. Zuechtungsbiol.* 101:210–219.
- van Dorp, R. T., S. W. Martin, M. M. Shoukri, J. P. Noordhuizen, and J. C. Dekkers. 1999. An epidemiologic study of disease in 32 registered Holstein dairy herds in British Columbia. *Can. J. Vet. Res.* 63:185–192.
- Whist, A. C., and O. Østerås. 2007. Associations between somatic cell counts at calving or prior to drying-off and clinical mastitis in the remaining or subsequent lactation. *J. Dairy Res.* 74:66–73.
- Whitaker, D. A., J. M. Kelly, and S. Smith. 2000. Disposal and disease rates in 340 British dairy herds. *Vet. Rec.* 146:363–367.