# A retrospective study of selection against clinical mastitis in the Norwegian dairy cow population

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#### Abstract

Clinical mastitis defined as a veterinary treatment recorded between 15 d prepartum and 120 d postpartum has been utilised in the national selection scheme since 1980. Economic weight for milk yield compared to mastitis in the total merit index was 4.5:1 in favour of milk yield. From 1990 it became 1.6:1 and later 1:1. First lactation records from 1.7 million cows between 1978 and 1998 have been analysed. Each year 40% would be daughters of 5 year old test bulls and 60 % daughters of 9 or 10 year old elite bulls. There were substantial non-genetic influences during this period. Milk quality payment according to bacterial and somatic cell count increased veterinary treatments. In 1995 the authorities launched a successful campaign to reduce antibiotics in agriculture by 25%, creating confounding with the selection pressure on mastitis. Therefore, calving month by year was defined as a fixed effect to remove external influences. Breeding values for mastitis frequency increased negligible for bulls born between 1971 and 1989, while for bulls born between 1990 and 1993 they improved by 0.43% pa.

#### 1. Introduction

Mastitis is considered the most costly disease for Norwegian milk producers (Waage, 1989). It is the most frequent veterinary treated disease of dairy cows and the cost of each case was estimated to 3000 NOK (Steine, 1996). The costs include veterinary and treatment costs, milk discarded due to bacterial and antibiotics contamination, reduced milk production for the remaining lactation, decreased milk quality, extra labour, early culling and increased risk of future disease. In Norway, antibiotics have to be prescribed and administered by a veterinarian, therefore mastitis is more expensive compared to other diseases than it might be in many other countries.

Veterinary treatments have been registered for each cow on a national basis since 1975 (Solbu, 1983). The milk recording system was revised in 1978 and contains information from the cow's health cards since then. Data digests for genetic evaluation was extracted each year for the most frequent diseases. Mastitis was scored as untreated (0) or one or more treatments (1) and a sire model was used to rank test bulls within a cohort based on their first and second lactation daughters (Fimland, 1984). Mastitis has received weight in the total merit index since 1980. The relative weight of milk yield compared to mastitis started out as 4.5 to 1, but has gradually changed over time into equal weight as shown in Table 1.

The breeding plan for the Norwegian dairy cattle (NRF) population was designed to cope with a broad breeding goal and low heritability traits. Each year the cohort contains about 125 test bulls, which sire 40% of the cows. This enables progeny testing based on 250-300 daughters per sire. The ranking within cohort is reliable even when only daughters of test bulls are utilised and the system has been robust and feasible in a computing mainframe environment. However, ranking across cohorts and

estimation of selection response has not been possible. Furthermore, the Norwegian herds are small so including the daughters of elite bulls and pooling the whole history of cohorts would be beneficial. This was implemented in 1999 and the objectives of this paper were to describe the data and model used in the implementation; and to investigate the response to the selection pressure applied against mastitis.

## 2. Materials and Methods

### 2.1. Data

Data digests for genetic evaluation of health traits within a single cohort of test bulls were made every year since 1978. The digests contained records of all first, second and third lactation cows with calving date within a range suitable to include the daughters of test bulls being progeny tested. The overlap between digests prior to 1992 was not complete, leaving out cows with calving dates from May to July. However, these were the months with least frequent calving. From 1992 an extra digest for long-term storage was made in December to reach more daughters at 120 days postpartum.

The records contained sire and cow identification, birth date, calving date, parity, culling date and reason, number of treatments and date of first treatment for each of mastitis, ketosis, milk fever and retained placenta. There were also the sum of treatments for various reproductive disorders and the sum of all treatments.

Mastitis was defined as a binary trait where a cow was considered treated with one or more recorded treatments for clinical mastitis (acute or chronic) between 15 days prepartum and 120 days postpartum. Most herds participate in the health card system, for 1996 the figure was 98% of recorded cows (NML, 1997). However, data from herds with no recorded treatments at all in a digest were discarded from that digest. Furthermore, if a cow appeared with the same parity in two digests, the newer record was kept. Also first parity cows younger than 21 months or older than 33 months at calving were discarded. The result of pooling the digests from September 1978 to 1998 is shown in Table 1.

Number of first parity cows was lower prior to 1991 because of lacking overlap between digests (two to four empty months) and lower participation in the early years of the health card system. The frequency of treatments only contains the cases that the farmer found severe or economically beneficial to veterinary treatment. Because a veterinarian must administer antibiotics, probably all severe cases are recorded. However, pricing policies and economics in general will influence whether a veterinarian is called to a less severe case. From 1986 somatic cell count (SCC) was included in the basis for milk payment. This made veterinary treatment more beneficial because of the effect on SCC for the rest of the lactation. The increasing treatments of clinical especially mastitis, clinical chronic mastitis (Helsetjenesten for storfe, 1998) and profylactic treatment at dry off made it politically feasible to launch a campaign in 1995 to reduce the volume of antibiotics used in agriculture by 25% before year 2000. This resulted in reduced frequency of treatments, but also a much more targeted treatment practice as reflected in the SCC in Table 1.

#### 2.2. Connecting structures in the data

In Norway purchase of bull calves for a new cohort begins at fall and continues through spring. About 400 calves are bought at two months of age and tested for growth rate from 3 to 12 months of age, and for semen producing capacity when they reach sexual maturity. A few times a year, contemporaries are evaluated and selected for progeny testing. This way the 400 are reduced to 130. The test bulls are used simultaneously from fall one year to spring the next with about 2500 doses each. As the daughters grow, each test bull produces up to 70.000 doses before slaughter. When the daughters complete first lactation the test bulls are evaluated by a total merit index in June. The semen stored from the selected elite bulls are then released from fall and used over the next two years. Each year, 40% of the cows is sired by test bulls from two cohorts and 60% of the cows is sired by elite bulls from three cohorts. This way overlap is created over generations and genetic structure over years as shown in Table 2.

2.3. Model

The 1.7 million records were analysed by the following mixed linear model:

$$\begin{split} Y_{ijklm} &= A_i + MY_j + hy_k + s_l + e_{ijklm} \\ \text{where} \end{split}$$

 $Y_{ijklm}$  was an observation of mastitis (0 = no mastitis, 1 = mastitis) of the m<sup>th</sup> first lactation daughter of the l<sup>th</sup> sire,

 $A_i$  was a fixed effect of  $i^{th}$  age at calving, i=1 to 13,

 $MY_j$  was a fixed effect of  $j^{th}$  month by year of calving, j=1 to 255,

 $hy_k$  was a random effect of  $k^{th}$  herd by year class, k=1 to 408.000,

 $s_1$  was a random effect of the l<sup>th</sup> sire, l=1 to 3601, and

e<sub>ijkl</sub> was a random error term.

Because mastitis was defined as a binary trait, the variance depends on treatment frequency. Table 1 shows that the treatment frequency varied considerably over time. Therefore the data from each year was standardised to equal variance before analysis. The following variance structures were assumed:

**hy** ~ N(**0**,  $I\rho_{hy}^{2}$ ), **s** ~ N(**0**,  $A\rho_{s}^{2}$ ) and **e** ~ N(**0**,  $I\rho_{e}^{2}$ );

where **A** was the numerator relationship matrix based on father and maternal grandfather of the sires. BLUP of the breeding values given variance components was obtained utilising the DMU5 program for iteration on data (Jensen and Madsen, 1996).

REML estimates of the variance components were obtained under the same model, but on a subset of the data and assuming unknown maternal relationships among the sires utilising the VCE4 program (Neumaier and Groeneveld, 1998).

### 3. Results and Discussion

#### 3.1. Model selection

In the analysis of field data there is often a dilemma of confounding between genetic progress and environmental trend. This material was strongly influenced by increasing treatment of clinical chronic mastitis until 1995 and then a successful campaign to reduce antibiotics in agriculture. Up to 1990 there was a stable selection pressure against mastitis and then considerably increased weight on mastitis (Table 1). Unfortunately the daughters of the first cohort of bulls purchased on basis of the new weights (1990-1991) started their lactation in the fall 1995, as seen in Table 2. Thereby creating confounding between the campaign and the increased selection pressure against mastitis.

Including a fixed effect of herd by year in the model would reduce bias in the genetic evaluation. The ranking within a cohort is robust, but part of the genetic progress may be included in the fixed effect. However, Norwegian herds are small and taking herd by year as random would preserve information. Therefore the combination of year by month of calving as fixed and herd by year as random was chosen.

Heringstad *et al.* (1999b) validated similar models by the method of Boichard *et al.* (1995) and concluded that herd by year or herd by 4 years as fixed removed the bias from their estimates of genetic trend. Unpublished results by the same authors showed that the combination of year as fixed and herd by year as random was only slightly biased, but much more suitable to preserve information for ranking purposes. Their model with herd by 4 years as fixed might have been preferable, but the abrupt change in treatment frequency would necessitate 1995 as the last year in a 4 year period and create a shorter last period some years.

Year	1 <sup>th</sup> lactation	Mastitis <sup>i</sup>	SCC <sup>ii</sup>	Relative weight	Ratio <sup>iii</sup> of
	records	Frequency	$10^{5} \mathrm{ml}^{-1}$	on milk yield	weights
	n			%	milk yield /
					mastitis
1978	22825	8.2		51	
1979	64100	9.2		51	
1980	48891	10.1	236	33	4.5
1981	52464	10.5	237	33	4.5
1982	57826	11.5	247	32	4.5
1983	86223	11.7	233	32	4.5
1984	70321	11.3	245	32	4.5
1985	70349	12.2	248	32	4.5
1986	69917	12.3	229	32	4.5
1987	82675	13.7	221	32	3
1988	86865	15.0	212	32	3
1989	90895	15.9	209	32	3
1990	86590	18.8	206	19	1.6
1991	97435	17.7	204	19	1.6
1992	99833	18.5	204	19	1.6
1993	98100	18.6	194	19	1.6
1994	103001	20.1	186	19	1.1
1995	99544	19.4	166	19	1.1
1996	98822	16.9	162	19	1.1
1997	98950	16.1	160	21	1
1998	98707	14.6	158	21	1
Sum	1705196				

Table 1. Number of first lactation records, mastitis frequency, somatic cell count (SCC) in bulk milk and total merit index weights used for milk and mastitis

<sup>i</sup> Mastitis as a binary trait. Untreated cows were scored as 0; while cows with one or more treatments between 15 d pre partum and 120 d post partum were scored as 1.

<sup>ii</sup> Arithmetic mean of all samples of bulk milk delivered to the processing industry in Norway (Helsetjenesten for storfe, 1998).

<sup>iii</sup> Percent weight on milk yield in the total merit index divided by the percent weight on mastitis in the total merit index

#### 3.2. Variance components

The following REML estimates of variance component ratios were obtained:

 $\begin{array}{l} h^2 = 4 {\rho_s}^2 \, / ({\rho_{hy}}^2 + {\rho_s}^2 + {\rho_e}^2 \, ) = 0.032 \\ c^2 = {\rho_{hy}}^2 \, / ({\rho_{hy}}^2 + {\rho_s}^2 + {\rho_e}^2 \, ) = 0.073 \end{array}$ 

The heritability estimate was very similar to the findings of Heringstad *et al.* 

(1999a) when herd by year was considered fixed.

3.3. Reliability in the selection index sense

Table 3 shows the correlation between true breeding value and index for a hypothetical selection index situation using the SIP program (Wagenaar *et al.*, 1995). To compensate the loss of information due to small herds, the effective number of daughters in the evaluation for milk yield of 230 was used instead of the actual number of daughters of 300. The reliability decrease rapidly with decreasing heritability, but the heritability obtained from this material still allow reliability of about .8 in a breeding structure similar to that of the NRF population.

#### 3.4. Genetic progress for mastitis

Figure 1 depicts average sire solutions for first crop daughters. The test bulls are 5 years of age when their daughters calves and these daughters constitutes 40% of all primiparous cows that year. Test bulls are equally used within a cohort so Figure 1 represent half their genetic trend. The ratio of relative total merit index weights between milk yield and mastitis changed in 1990 and the effect was expected to become visible in first crop daughters 5 years later. Figure 1 shows that the rate of improvement between 1995 and 1999 was .58% per year. However, these sire solutions were scaled because data from each year had been adjusted to a standard deviation of 1. Assuming a population treatment frequency of .17 and multiplying by 2, we obtain an estimated genetic trend of .43% improvement per year in this period. Figure 1 also show that the total merit index weights prior to 1990 have been adequate to allow progress for milk yield without an unfavourable genetic change in mastitis. This was in accordance with the findings of Heringstad (1999).

Daughters Calving				Bulls born, y	ear		
Voor	84/85	85/86	86/87	87/88	88/80	80/00	00/01
i cai	04/05	85/80	80/87	07/00	00/09	89/90	90/91
1990	XXXXX						
- / / •		XXXXX					
1991		XXXXX					
			XXXXX				
1992			XXXXX				
				XXXXX			
1993	WWWWW			XXXXX	VVVVV		
1004							
1994	YYYYY	YYYYY			λλλλλ	XXXXX	
1995	YYYYY	YYYYY				XXXXX	
1775		YYYYY	YYYYY				XXXXX
1996		YYYYY	YYYYY				XXXXX
			YYYYY	YYYYY			
1997			YYYYY	YYYYY			
				YYYYY	YYYYY		
1998				YYYYY	YYYYY		
					YYYYY	YYYYY	
1999					YYYYY	YYYYY	* ** ** ** ** ** *
						YYYYY	YYYYY

Table 2. Patterns of bull usage in the breeding plan of the NRF population. Each year 40% are daughters of test bulls and 60% are daughters of elite bulls. Daughters of test bulls are marked with XXXX, while daughters of elite bulls are marked with YYYY



Figure 1. Average sire solutions for clinical mastitis and milk yield for first crop daughters of test bulls. Data on clinical mastitis was scaled to unity standard deviation within year of calving. First crop daughters constitutes 40% of the primiparous cows each year



Figure 2. Average sire solutions for clinical mastitis and milk yield for second crop daughters of elite bulls. Data on clinical mastitis was scaled to unity standard deviation within year of calving. Second crop daughters constitutes 60% of the primiparous cows each year.

Table 3. Correlation between the true breeding value and the index  $(r_{TI})$  in a situation with 230 daughters only, and in a situation with a sire/maternal grandsire model (230 daughters, 230 paternal half sisters, 230 paternal aunts and 230 maternal aunts)

1.00			
	Heritability	Daughters only	Sire/maternal grandsire model $r_{TI}$
_		$r_{\mathrm{TI}}$	
	0.02	0.732	0.760
	0.03	0.797	0.816
	0.04	0.834	0.850
	0.05	0.863	0.874

The effect of change in total merit index weights in 1990 on the selection and utilisation of elite sires can be seen in second crop daughters from 1993 onwards (Figure 2). There has been considerable improvement for mastitis at the expense of milk yield. However, from Figure 1 it seems to have been sufficient supply of bull sires excellent for both mastitis and milk yield to keep up genetic progress for milk yield in the test bulls. The crucial point for that to happen is testing enough bulls for these combinations to show up.

The estimates in Figures 1 and 2 comply well with the weights used in the total merit index from 1978 till now. Risk per cow and year of veterinary treatment for mastitis have developed in a similar manner to the mastitis frequency in Table 1 (Helsetjenesten for storfe, 1998). When they divided clinical mastitis in acute and chronic, the risk of acute mastitis treatment increased linearly from 0.20 in 1980 to 0.24 in 1994 and then decreased linearly to 0.18 in 1998. The risk of chronic mastitis increased four times faster, from 0.02 in 1981 to 0.17 in 1995 and then decreased to 0.12 in 1998. This supports the believes that the increased treatment frequency until 1995 was related to economic benefit of reducing SCC and not to increased ability of milk yield. The development in average SCC in bulk milk (Table 1) shows better correspondence with the genetic change. The changed total merit index weights in 1990 was expected to show in first lactation second crop daughters in 1993; then in first and second lactation second crop daughters in 1994; followed by second and third lactation second crop daughters and all first lactation cows in 1995. It can only be speculations, but this increasing genetic impact correlates very well with the large yearly improvement in bulk milk SCC (Table 1) between 1993 and 1995.

### 4. Conclusions

Data from the national health card system have enabled genetic selection against mastitis. The weights used in the total merit index until 1990, allowed genetic progress for milk yield without unfavourable response in mastitis. The weights used later have allowed genetic response for mastitis at some expense of response in milk yield in the cow population, but so far without reduced response for milk yield in the sons. Large daughter groups together with proper weights are necessary for reliable and effective selection against mastitis. The yearly cohort of test bulls must be large to secure the existence of enough bulls excellent for both milk yield and mastitis to be used as bull sires.

## Acknowledgment

G. Klemetsdal and B. Heringstad are acknowledged for assistance and valuable discussions during the implementation of new breeding values for mastitis and health traits.

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